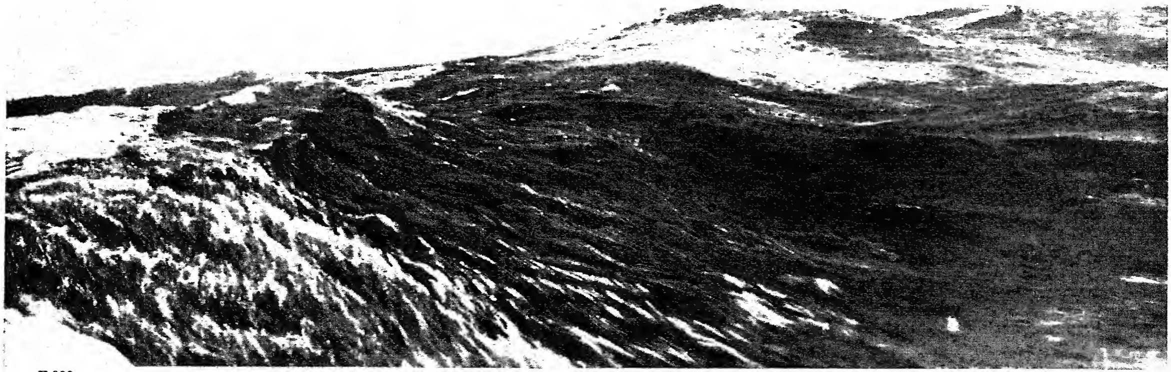
THE SEA
AND ITS WONDERS



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"HEAVY SEAS" IN THE NORTH ATLANTIC

Frontispiece.

THE SEA
AND ITS WONDERS

BY

CYRIL HALL

Author of "Triumphs of Invention," &c., &c.

With thirty-two half-tone plates
and other illustrations

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CHAPTER I

The Oceans Come to Earth

Very few people know much about the sea. "They that go down to the sea in ships, that do business in great waters; these see the works of the Lord, and His wonders in the deep." Yet, though ships have been sailing up and down the world for thousands of years, the Psalmist's words are true of only the merest handful of men in any generation. Even in our own age—the age of transport—comparatively few people have been to sea. The vast majority can never do so, for they live too far away from it. I read in the newspaper the other day an appeal by a Leeds clergyman for funds to enable him to send to the seaside 12,000 children in that city who had never seen the sea. Yet the coast is within a train journey of an hour and a half!

Although it is the fortune only of the few to know much of the sea at first hand, every one of us is linked to it in a strange and wonderful way. For all things living came originally from the sea—animals and plants of the dry land, birds and insects, as well as the beasts and plants that live in water—all are developed from elementary living organisms

that had their beginning in the oceans of past ages. And in a sense we are still creatures of the sea, for we all depend upon water for our existence, and all water, whether rain, dew, snow, mist, or cloud, comes from the sea and returns to the sea in a never-ending cycle. Our bodies are largely made up of water, about 90 per cent of all our weight being water; and it is strange to think that our blood is essentially salt water with other things in it.

If we glance at the map of the world, or better, at a globe, we see at once that the space occupied by the sea is far greater than that occupied by land. Indeed, nearly five-sevenths of the surface area of the globe is given up to the oceans. We must notice, too, that the northern has a much larger proportion of land than the southern hemisphere; and although it is possible to divide the earth into a land hemisphere and a water hemisphere, even the land hemisphere contains less land than water, while in the water hemisphere the land area amounts only to one-tenth of the whole. The explanation of the disproportion of land and water—how it has happened that the oceans and the continents occur as they do—is an interesting and fascinating subject, consideration of which must be deferred for a little while.

How, then, shall we start our survey of the sea? From what vantage ground dip into its deep mysteries? To begin at the very beginning would take us beyond our depth into speculations on cosmic evolution, but we may be allowed to ask ourselves such fundamental questions as how the salt and water came to make the seas. To find answers to these questions we must take our minds through the immeasurable æons that lead back to the morning of the world.

We may observe the earth for a few moments in its infancy. There is no doubt that the earth was born of the sun, whatever may have been the method, the cataclysm, by

which the partition came about. And—its birth in that manner once accepted—no one doubts that it once was molten. There is plenty of evidence of that, of course—direct evidence. The igneous rocks; the occurrence of tin, copper, gold, and other metals in veins and fissures in which they seem to have condensed from gases originating deep in the earth; the very high temperature believed to exist only a little way beneath our feet—such things point to a fiery stage in our planet's history. You know, probably, that if you dig a hole your descent into the skin of the earth will be accompanied by a rise in temperature. The increase is not quite constant; it varies according to the conductivity of the rock passed through; but below a depth of 200 feet it rises in the average ratio of one degree Fahrenheit for every 200 feet. A year or two ago some American engineers bored the deepest Artesian well in the world; water-bearing strata were penetrated at a depth of 8000 feet. Water from this well is boiling when it reaches the surface. But then, hot springs are common enough; and very fascinating too. I never see the steamy, hissing hot water gushing from the rock at Bath, gushing now just as it gushed for the Romans, but it touches my imagination in spite of the washing-day smell. But what a tame affair in comparison with the geysers of Iceland and New Zealand!

Scratch the surface of the earth, where you will, and you will find it hot underneath. Men have never done more than scratch it. A hole two miles deep—10,500 feet—sounds a deep hole, but what is it in relation to the mass of the earth? The veriest pin-prick! It is 4000 miles to the centre of the earth. I suppose if you took a nice-sized onion and rubbed off a wafer of its beautiful membranous skin, the wafer might represent to the mass of the onion the equivalent of a two-mile hole to the mass of the earth—something like it, roughly speaking. So we only know by inference what are

the conditions below the earth's crust. That very picturesque astronomer, Camille Flammarion, once proposed a shaft five miles deep for the study of the inside of our queer little globe. One cannot suppose he would have learnt much that he did not already know. Hot inside, it certainly would be; and as to how the heat got there, you can take the common view that it is the residual heat of the fiery wave torn from the side of the sun, or (to go farther back still) the residual heat of the original nebula from which the sun itself condensed. You can amend or supplement this by the heat arising from the earth's contraction, and by the presence in its interior of radio-active substances. As to that I cannot help you much; the problem is too complicated. But we must accept it that the earth was once much hotter.

What an earth! So strange, weird, scarcely imaginable. Could Homer, could Dante, could Shakespeare disclose for us a single flash of the unutterable fierceness of the primeval furnace in which this globe was wrought—could any poet pierce for an instant the veil shrouding the surging molten tides in which arose the kindly living world we know and love, we might, I suspect, apply to our tasks a keener, richer sense of the underlying Truth. But to get the liveliest notion of what the world's infancy was like—at best a sort of loose, pictorial notion—take all the imagination you can boast, feed it with all you have ever seen or read of fire—of all that seems most terrific, all that stimulates your notions of the terror, of the fierceness and fury belonging to things molten, seething, roaring, consuming. Take earthquakes and tidal waves, volcanoes, the crashing, irresistible motions of the wildest storms. Take them and magnify them a million times and then, perhaps, we may have a glimpse of the age-long morning of the world.

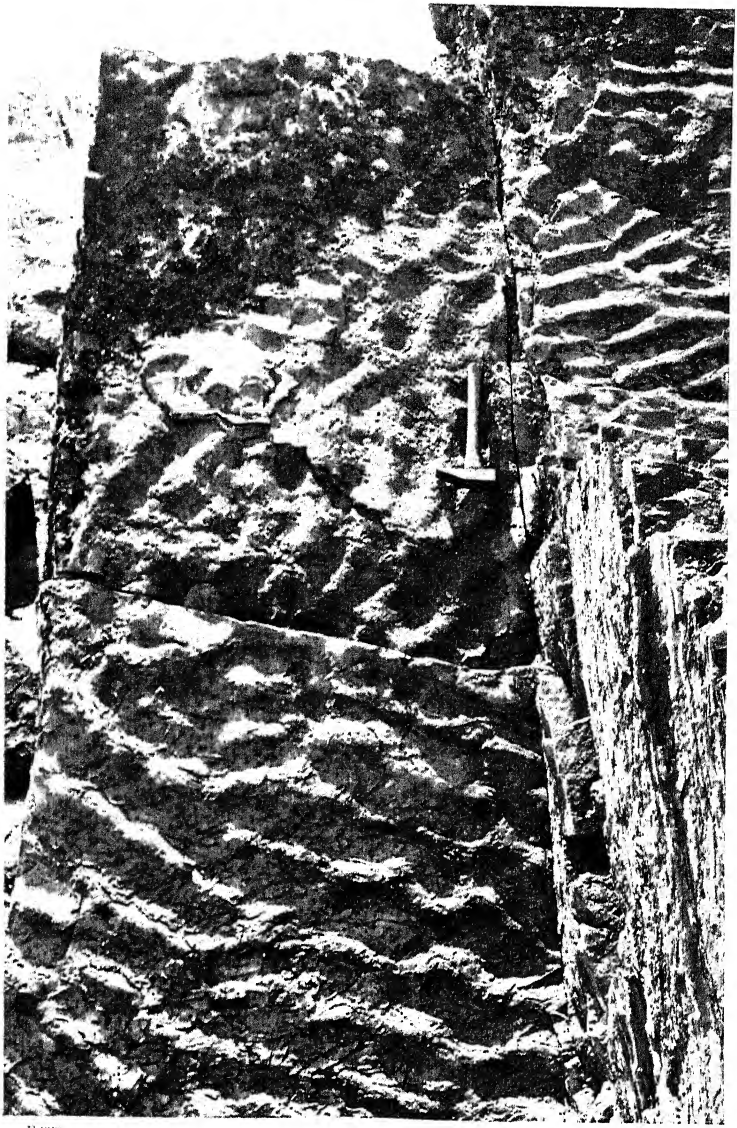
It was a much larger world in its infancy. And because it revolved four times as fast, night and day would have recurred in three-hour snatches, only, of course, there wasn't any night and day, for the sun could never penetrate the curtain of metallic vapour shrouding the boiling mass. This "atmosphere" must have exerted an enormous pressure on the surface of the molten sea—perhaps 5000 lb. to the square inch, instead of fifteen. But it would be subject to the influences working in our own atmosphere; there would be cyclones and anti-cyclones, cooler elements sinking, and lighter warmer currents rushing upwards. So it must have been with the molten sea. Tides ebbed and flowed while the dense metallic vapours swept and lashed it into billows; for though there was no moon then, the sun tugged and tore at its offspring and there would be a rushing of hot streams and cooler ones, a clashing and crashing of billows of molten lava at the surface of that dreadful sea, while the lightning rent the gaseous envelope and the thunder reverberated through its awful corridors.

So it must have spun, age after age, this boiling inferno of a world, ever losing its primitive heat, cooling, cooling all the time, the heavier elements of its constituents gravitating slowly to the centre. Because of the enormous weight of the atmosphere, solidification of the crust would begin at a very high temperature — something over 2000° F. probably, and on this first crust, forming where the pressure was greatest or where the coolest currents circulated, the molten waves thundered and crashed for still longer ages. There is a picture facing page 148 of the wind-roughened, wave-tossed pack-ice in the Antarctic sea. It gives us a clue, I think, to the first appearance of the wind-roughened rocks in their first consolidation. They were not roughened by winds of air, for air there was none, but by the

hurricanes in the ponderous gases in which the earth must have been enshrouded.

Somehow in that way emerged the earliest rocks. The cooling globe contracted; its rate of spinning slowed down; it gradually assumed its present shape. Slow it down a trifle below its present rate of 5000 feet a second and it would become a perfect globe; speed it up a little, and it would begin to bulge again at the equator and thitherwards we should all go slipping—houses, ships, everything. But the more the earth solidified the more it contracted, and the heat of the contraction would retard the solidifying process. The newly-formed "skin" buckled, crumpled, cracked, gave way where it was weakest to release the pressure of the internal furnaces. Here volcanoes ruptured it, there it was torn and tossed by earthquakes. So the process was repeated again and again down those unlit avenues of Time. But bear in mind no sudden cataclysm left much permanent impression on the carving of the earth we know. Enduring scars there are, here and there, but for the rest, it has been the gradual shrinkage that has laid the foundations upon which we have our earthly being—the gradual elevation of the lighter earth-masses and the subsidence of the denser. The ups and downs, the Himalayas and the abyssal deeps of the ocean are like the folds and wrinkles that you may see in the skin of a withered apple. Only, remember, much less in proportion. You could not show the Himalayas on a model of the earth the size of an apple.

While the earth was cooling, all the water must have been in a dense curtain surrounding it; a gigantic veil of heavy water-vapour two miles deep or more, exerting on the earth a pressure of thousands of pounds to the square inch. In time, as conditions became physically and mechanically favourable for condensation, hot rain would pour upon the hotter rocks, to flash back into steam again. But at last water



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RIPPLES OF FORGOTTEN SEAS

Ripple markings in Old Red Sandstone Flags, N.-W. Coast of Island of Fara, Orkney

Facing page 14.

stayed on the earth. A hot sea collected in the deepest hollow, and real watery waves beat upon the ever-cooling granite. It was the first, the pristine sea.

How long ago was that? I suppose, since all such questions touch our imagination, and the human mind gropes backwards almost as eagerly as it gropes forwards, this one deserves an answer. Yet the answering is an excursion that really does not help us much. Lord Kelvin, you may remember, put the earth's age at 400 million years. Modern biologists demand an infinitely longer span for the development of life to its present forms; they are not even satisfied with the newest estimates based on radio-activity, which allow 1500 million years since the earth solidified.

How did the salt get into the sea? This interesting question, like many another in oceanography, is not so easily answered to-day as it was thought to be forty or fifty years ago. The salt came—and still comes—out of the land. The chief atmospheric gases are all soluble in rain-water and are potent forces in dissolving the rocks. The rain that came out of the sea returns thereto with a mighty interest; it carries not merely the detritus of the rocks—the sands and the muds that become spread over the sea-floor bordering the land—but the salts of the rocks in solution. Estimates of the amount of saline matter carried into the oceans vary between 2,700,000,000 tons and 5,000,000,000 tons in a year. Accept which figure you will—either overwhelms the mind. Ever since rains fell, the salts have poured into the sea, millions upon millions of tons accumulating during millions and millions of years. What wonder the sea is salt! Accurate measures have not been taken over a sufficiently long period to give any indication of the increase of salinity, but increase there must inevitably be. There have been attempts to estimate the earth's age from the quantities of salts carried down by the rivers, and working on those lines

Professor Joly thought it must have taken a hundred million years for the oceans to have attained their present degree of saltness. We know now that such a figure is entirely inadequate as an approximate estimate of the earth's age; we need at least fifteen times the hundred million years since its solidification. And the question is further complicated by modern arguments in favour of the oceans having been salt from the beginning. When the earth was smothered in the gases of its formative period there must have been an abundance of those products, sulphates and chlorides, in which the ocean is now rich.

The actual composition of sea-water is always the same, from whatever ocean or whatever depth it may have been taken for examination. Rather more than three-quarters of its saltness is made up of sodium chloride—common salt—and the remainder of the salts held in solution are mostly small quantities of the chlorides, sulphates, bromides, and carbonates of magnesium, calcium, and potassium, with minute traces of other things. Nearly half of the eighty known elements are traceable in sea-water, and there have been grandiose but entirely impossible schemes for extracting from it precious metals like gold. But if you added to pure water all the necessary chemicals to give it exactly the composition of sea-water you would not really have an exact imitation, because you would not be able to endow the molecules with the power to split into the negative electrical particles which is known as ionization or dissociation. Sea salts are largely ionized, and because of this you cannot make a real sea-bath out of tap-water and a handful of evaporated sea salts. But though the constituents vary only so slightly in number and proportion that they are practically constant, the degree of concentration does vary very considerably. It might be supposed that the salinity—the variation of saltness—of the sea in

different parts of the world could not be a matter of very great interest or importance. Yet the question of salinity is almost sure to crop up whatever aspect of sea science we choose to investigate. But we mustn't stop to consider the subject now. I hope to make its influence clear as we go deeper into the story of the wonders of the sea.

Now, before we go under the sea, to find out what things are like in that preponderating area of our earth of which we have, most of us, only superficial knowledge, it will be just as well to make a mental model of our globe, as it were, so that we can get a fair idea of the general distribution of land and water. Let us first fix in our minds the positions and relative areas of the great continental land masses in their general bearings to the oceans. For my own part, I find the terms of the geospheres helpful in any mental picture of the earth as a ball swinging in space. It will help to make what follows clearer if we picture it as composed of a series of concentric layers or shells, each interacting upon the others. These are the geospheres.

First, the atmosphere, the earth's gaseous envelope, a mixture of oxygen and nitrogen with carbonic acid, water in the form of vapour, small quantities of rare gases like argon and neon and also dust, a constituent that we are apt to overlook. Dust is found throughout the atmosphere, wherever it has been examined. It is carried to immense heights and immense distances, even circling the world, as in the case of dust from volcanoes.[1] Most of it is terrestrial, but there is always a good deal of what is called cosmic dust in the air, resulting from the constant collisions of the earth and meteorites. We shall come across the meteoric dust later on, and we must likewise reserve the

[1] Dust from volcanoes has been known to circle the globe at least three times, travelling at a height of eight miles, at a speed of ninety miles an hour.

changes in the equilibrium of the atmosphere until the time comes to talk about the winds. All that we need bear in mind now is the fact that the gases of the atmosphere are absorbed by the ocean, and carried, in one way or another, to its lowest depths.

Next comes the hydrosphere, the subject of our story,

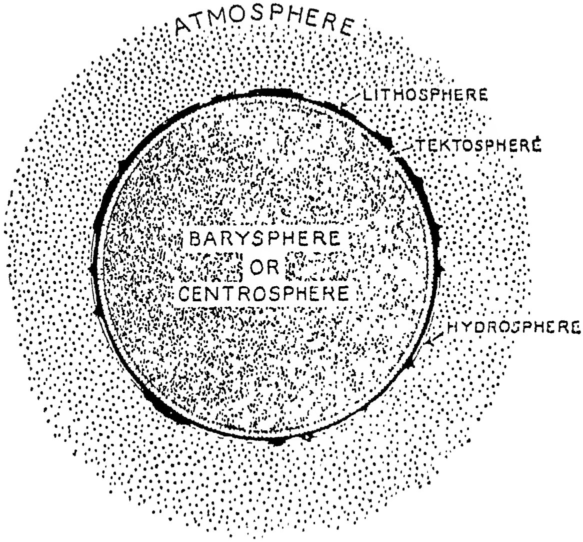


Diagram of the Concentric Zones of the Earth

though strictly the hydrosphere embraces all the watery layer of the geosphere, whether in the ocean or the atmosphere, in the rivers or the perpetual ice of the unreachable mountain-tops. And then the lithosphere, the rocky crust that is mother earth to us all. We have dug into the lithosphere to a depth of several miles and we know pretty well by now what it is made of. The rocks are heterogeneous —very much mixed. Some have clearly solidified from once molten material. Others—and these form most of

the surface layer of the lithosphere—are sedimentary rocks. They are made of the particles of earlier rocks, broken up by wear and tear, that have settled down gradually under water. Thus the quartz of granites made the sandstones, the muds and clays have become shales and slates, while nearly all the chalks and limestones in the world are the fossilized remains of sea-creatures. Millions of years must have gone to the making of the sedimentary rocks; they are often thousands of feet in thickness.

The heterogeneous materials of the lithosphere form, it is thought, a layer or sphere from thirty to forty miles thick. Thirty or forty miles may sound a good deal, but if you think of it in proportion to the earth's diameter, nearly 8000 miles, it appears as no more than the wrinkled skin of the world.[1] It is quite correct to view the contours of the earth's surface—the great continental blocks with their mountain ranges and the greater depressions containing the oceans—as largely the result of the wrinkling and crumpling caused by the pressure set up by the earth's shrinkage. There is reason to suppose that the earth masses that have been raised highest are composed of lighter materials than the earth masses that are most depressed, although no means have yet been found for penetrating more than a few feet into the lithosphere where it lies beneath thousands of fathoms of ocean. The equilibrium of the materials of the crust—the assumption that the height of a mountain and the depth of a basin are dependent on their weight—is known as isostacy, or isostatic balance. This question of the relative specific gravity of the different masses of the earth's crust is a very interesting one. The earth as a whole is five and a half times as heavy as water; and more than

[1] On a globe 2 feet in diameter, Mount Everest's 29,000 feet would have to be represented by a projection $\frac{17}{1000}$ inch high, and the deepest oceans by depressions $\frac{2}{100}$ inch deep.

twice as heavy as granite. The inside of the earth must therefore be made of very much heavier material.

The great central core or centrosphere—it is sometimes called the barysphere, from the Greek word *barus* meaning heavy—is believed to be composed mainly of iron, nickel, gold, platinum, and other heavy metals. It was once thought to be liquid; but in spite of its very high temperature, it is much more probably solid. Consider the immense weight imposed by the superincumbent rocks, which at so slight a depth as ten miles must equal a pressure of thirty tons to the square inch, and it becomes difficult to think of the centrosphere as being in anything but a solid state. It does, indeed, behave as if it were more rigid than steel, for vibrations set up by earthquakes travel through the centrosphere of the earth at the rate of six miles a second—much more rapidly than they travel through steel. Remember that solids are *fluidic* under pressure. A lump of clay *flows* between the fingers; a steel ingot, in the hydraulic press.

The great centrosphere, whatever it is made of and whatever its condition may be, anyhow represents by far the greatest mass and volume of the earth. Scientists have quarrelled a good deal about the earth's inside, but they now generally admit the probable existence of another geosphere, called the tektosphere, intermediate between the centrosphere and the lithosphere.

This tektosphere can be thought of as a molten sphere, or more accurately as a sphere in which the rocks may change from molten to plastic or solid, according to variations in pressure from within or without. It is a sort of balancing medium, just beneath the thirty-mile crust, through which the shrinking of the centrosphere as it cools is adjusted without disturbance to the lithosphere. To put it in a rough sort of way, the plastic lava-like material of the tektosphere gets squeezed into the "gaps" that would

otherwise be formed between the diminishing centrosphere and the more or less rigid crust. But for this compensatory medium, we may suppose that the lithosphere would be still crumpling and wrinkling in a manner very alarming to its living burden, in spite of its thirty-mile thickness.

With a clear picture of the geospheres we can better observe the ocean. Is it but a glorified puddle in the lap of the lithosphere? No, on a second view, the part of the lithosphere that we call the dry land is a rather insignificant table-land sticking out of the hydrosphere. The mean depth of the ocean is 12,500 feet; the average height of the land is only 2250 feet. That is, it would work out at that general height above sea-level if we cut down and levelled off the mountain ranges. But if we levelled off the mountain ranges and shovelled them into the depths of the ocean, the depth of the ocean around the whole world would still be about 10,000 feet. The floor of the ocean basins, *the abyssal area* as it is called, is estimated to have an average depth of 15,000 feet. The hydrosphere takes on its right proportions when we realize that this abyssal area, more than two and a half miles deep, covers 100 million square miles, or more than half the earth's surface. The greatest known depth of the ocean, in the Philippine Trench off Mindanao in the Pacific, is 35,400 feet. If you could drop Mount Everest in this deep, its summit would be covered by 6398 feet of water. From the top of Mount Everest to the bottom of the Philippine Trench, the greatest known irregularity in the surface of the earth, is a drop of nearly twelve miles.

And now, thinking of earth as a globe swinging in space, let us see how land and water come by their present arrangement.

CHAPTER II

Riddles of the Earth-plan

Has it ever occurred to you, in looking at the map of the world, that the divisions of land and water present some extremely interesting features? Here's a continent—there's an ocean; and as to the *why* and the *how* of their being where they are, that is the business of physiography to explain for us. It is true that there is not, as yet, an entirely definite and satisfactory explanation, but we can scarcely approach the study of the ocean without observing the strange facts presented by the plan of the earth.

So, if you please, a few minutes with the map of the world. If we can dig out a globe from some box-room or lumber-room to which a past and forgotten hatred once consigned it, so much the better—if there is not too much plaster missing, that is. Observe first, the great excess of land in the northern hemisphere. There is no need to go into the relative areas. A glance is sufficient to show that nearly all the land is crowded into the northern hemisphere, while the southern hemisphere is mostly ocean.

Observe, next, the generally triangular forms of the continents and oceans. The land triangles have a common tendency to taper southwards; the sea triangles consequently have their bases to the south and their points to the north. Although the triangles are irregular they are unmistakable. If you drew a chain of islands on the map between the Hebrides, Iceland, and Greenland, to indicate

a land area only recently vanished, geologically speaking, the North Atlantic would show more clearly as a rough triangle than it does now.

Observe now what appears as the outcome of our two previous observations. The land is seen as a broad belt which is not quite complete, but very nearly, girdling the northern hemisphere. The gap appearing in the North Atlantic is, as I have said, a relatively recent one; Scotland

Southern Hemisphere

Northern Hemisphere

used to be joined to Greenland. The other gap in the land girdle is Bering Strait, the shallow waterway between Asia and America. From this nearly complete land ring then, three great continental masses project and taper southwards, North and South America, Europe-Africa,[1] and Asia with Australasia.

And now for the fourth and the most curious of our observations. It is not at once apparent from the map, but if you have a globe it can soon be made. Look carefully and you will see that land and water areas are antipodal. The antipodes are the points on the circumference of the globe of any straight line drawn through its centre, and

[1] Frequently called Eur-Africa by modern geographers.

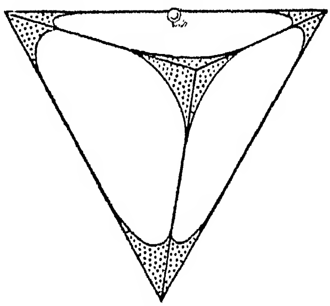
you will find of almost any line you like to draw straight through the centre of the earth that it has land at one end and water at the other. Not quite invariably; a line starting in the southern part of South America will come out in China, for instance; but only one twenty-seventh of the land of the world has land opposite to it. Each of the continents is antipodal to an ocean. Europe and Africa are opposed by the Pacific, North America by the Indian Ocean, South America by the Western Pacific and the China Sea, Australia by the North Atlantic, the Antarctic continent by the Arctic Ocean.

The four geographical "homologies" that we have just reviewed, must shatter the notion that might arise from less careful study of the map that the arrangement of sea and land was more or less haphazard. That, it clearly is not. We see evidence of a definite plan; and we seek to know the meaning of the plan, just as we should if we had before us a plan, not of the earth, but of a Roman villa or a Maya temple. We must ask geologists to read for us the riddle of the strange earth-plan, to explain the meaning of the four geographical homologies. Or have they no meaning? Are they just "accidents" or freakish coincidences in the shaping of the lithosphere? These questions postulate an unbelievable absurdity.

You have heard of a tetrahedron, a geometrical body made by four equilateral triangles. It is interesting as the form which provides for a given volume the largest possible superficial area; the sphere, as you know, is the form which provides the *smallest* possible area for a given volume. Suppose, now, you made a paper model of a tetrahedron and mounted it, on a cork or a piece of wood, with one of its four "corners" pointing directly downwards. Now, if water could be retained upon the surface of this model by attraction from its centre, as water is held upon the earth by

what we call gravity, the water would first collect in the centres of the four faces because they are the surfaces nearest the centre of the model. And if the water surface were increased to five-sevenths of the total surface of the model, the watery circle on each face would then extend until it joined up with the circumference of each adjoining circle. Five-sevenths is an important proportion, since it represents the ratio of sea-area to land-area.

Looking carefully at the figure of the tetrahedron retaining water on its surface (by a hypothetical gravity), to the extent of five-sevenths of the total area, the geographical homologies recur to us with a new interest. For instance, the dry areas—the four projecting corners—are antipodal to wet areas, just as the continents are antipodal to the oceans of the earth. The wet circles are the seas; the corners emerge as the ridged continental masses. If the centre of the uppermost surface be taken as the North Pole, it is seen as surrounded by the Arctic Ocean. The land-areas which nearly encompass it taper downwards, that is, southwards, and may be taken as the continental masses of America, Europe-Africa, and Asia. At the base of the tetrahedron is a land mass that may be interpreted as the Antarctic continent, while the sea, appropriately uniting at the edges of each face of the figure to form a continuous band, covers most of the lower part of it and extends upwards, that is, northwards, between the three land triangles. So you see the plan of the earth has its



A Tetrahedron in which the dotted and plain areas correspond in extent to the proportions of land and water on the earth. The water occupies the parts of the surface nearest the centre of the tetrahedron.

parallel in the plan of a tetrahedron with five-sevenths of its surface covered with water.

Yes, you say, that is all very well, but the parallel would be more convincing if the shape of the earth was tetrahedral, which it most emphatically is not. As to that, geographers have an answer ready—most of them, that is, for they do not all agree with Lothian Green, who first propounded this interesting and ingenious theory in 1875. No, they say, it is true that the earth is not a simple tetrahedron in form; but it is possible to place a six-sided pyramid on each face of a tetrahedron, which then nearly approaches a sphere. Further, if the pyramids were made of elastic material, and blown out, their faces would become curved, and the whole figure more nearly spherical still. Indeed, experiments on collapsible spheres—rubber balloons under pressure in water and so forth—actually show that a thin, hollow, elastic-sided sphere does collapse into a tetrahedral form; the sides cave in and leave roughly tetrahedral ridges.

And now, if we accept the tetrahedral form of the earth-plan, as most scientists are inclined to do, what is its explanation? We must assume that there are at least two forces which have been constantly at work in moulding the earth's shape. Though as to that, nobody seems quite to know what its shape is, exactly. It certainly isn't a true sphere. It is called a geoid, which means earth-shaped. "The earth is earth-shaped," said Sir John Herschel, not very helpfully. Sir James Jeans says it is pear-shaped, and Professor Gregory "like a badly made peg-top". Well, I know at least ten different kinds of pears, all differently shaped, and I fancy there is no strict adherence to form among peg-tops. The geography books of my schooldays informed me with complete confidence that the earth was an oblate spheroid—a shape something like a flattened orange. It is recently revealed that the earth is like an orange that has been gently

and delicately—sucked. A little sucked, no more. It is not merely flattened at the Poles, but flatter at one pole than the other, and the equator isn't even a circle; it is an ellipse. So the earth is not even a spheroid, oblate or otherwise.

Whatever the exact shape of the earth may be (which is being slowly learnt by very complicated calculations based on pendulum observations) its rate of revolution on its axis keeps it ball-shaped. The force which is at work to counteract the sphere of rotation, as it is called, is an internal one, and arises from the contraction of the centrosphere. This is where the tetrahedral formation—or more accurately, deformation—appears. The tetrahedron, remember, is the body which has the maximum surface for the minimum of volume. As the centrosphere shrinks, the crust—the lithosphere—has to adapt itself to the diminished volume. As Professor Gregory puts it, the earth " tends to that shape which most easily gets rid of the excess of surface due to its contraction; and it most easily gets rid of its excess of surface by sagging on the four faces, and thus collapses with a tetrahedral deformation ".

We may reasonably accept this as a natural, and, indeed, inevitable explanation of the earth-plan—the why and the wherefore of the oceans and the land. And another question here arises: Have the oceans always been where they are now? In all earth history there is hardly a more difficult question to answer. More than 1,500,000,000 years have probably elapsed since the waters condensed to form the first oceans, according to Sir James Jeans. Indeed, except that on our tetrahedral theory of the earth-plan the dry land emerged inevitably—becoming banked up, as it were, by compression along the lines of the most resistant rock masses—we have really no right to assume dry land as a necessary part of the earth. We think of land and water together; but there is so much water that a gravitational

change or a rotational change might have resulted in all water and no land. The bulk of sea-water is more than thirteen times the bulk of the land above sea-level, and if the earth was a true sphere of uniform density, it would be entirely covered by a film of water more than a mile deep. And how can we say, other than vaguely, what changes may not have taken place in the relative positions of land and sea in the span of fifteen hundred million years?

Yet there would appear to be so much clear evidence of sea-change and land-change—in other words, of the inconstancy of the oceans—that we cannot doubt the probability of lost continents and diminished oceans. Everywhere the hills reveal the secrets of the forgotten seas. What a different world was here, when " Asia from her bathing rose!" Hundreds of millions of years of earth-crumpling; of shrinkage, and its inevitable lowering of sea-level, of volcanic turmoil along the great geological fissures or " faults ", age after age, each age apparently succeeded by an age of volcanic quiet while Time's slow hand built anew upon the ruins—what need to ask, have land and sea always been the same?

In the Cambrian Period, the earliest of the Palæozoic Era, and the oldest known period of which we have any appreciable record of life on the earth, the oceans and continents were recognizably those of to-day. There would appear to have been three great northern continents tapering southwards. Europe and North America were united; the northern half of South America was possibly a great island, considerably larger than Australia. A narrow sea, covering southern England, the eastern half of Scandinavia and north Germany, separated Europe and America. Cambrian Africa had much its present shape, minus the Cape. Asia stretched in a gigantic peninsula running south-east to include Polynesia and part of Australia. The greatest

difference in the Cambrian map was a supposed Pacific continent separated from the eastern coast of what may be referred to as Asia-Australasia by one narrow sea, and from the western coast of America by another.

It is mainly on the fossil remains of corresponding animals and plants in similar rock strata of the same age in different parts of the world that geologists have built their world maps for the different geological periods. It is at least a reasonable assumption that animals that could not fly or swim must have walked or crawled from one place to the other, when we find their remains, or their successors, in continents now separated by thousands of miles of ocean. And this assumption presupposes land for them to walk over. The maps for the different geological periods show extraordinary changes in land and sea. Thus in Silurian times, North America is supposed to have been a scattered archipelago of five or six large islands; in the Cretaceous Period, the last of the Mesozoic Era, there seems to have been a great submergence which annihilated the Pacific continent of the previous Palæozoic Era. This was the ancient continent called Gondwanaland, after the district in India in which its deposits were first studied. Imagine a continent starting at New Zealand, covering Australia, spreading westwards across the Indian Ocean, absorbing Africa as far north as the 20th degree, then still spreading westward and terminating roughly at the westerly boundary of Brazil. That was Gondwanaland.

At the meeting of the British Association at Johannesburg in 1929, Professor Watson, the President of the Zoological Section, in supporting the Gondwanaland theory, traced the remarkable resemblances in the plants and the reptiles of Africa and South America. One such resemblance, of which there are many, is that of a snake, decynodon, which is found only in South Africa, South America, Madagascar,

India, and Australia, while the lung fish, which can live out of water as well as in it, is found in fresh water only in South America and South Africa, the two species being almost indistinguishable.[1]

Gondwanaland was washed on the north by the mighty Tethys Sea, of which the Mediterranean, the Black Sea, and the Caspian are supposed to be remnants. Tethys sent a sinuous tongue, south and then east, through Asia Minor, Persia, over the land where the Himalayas now rear their heads, then across the Bay of Bengal over the East Indies, and so joined the Pacific to the north of what is now Australia. Tethys flowed over Europe, except the north-west corner of Britain and Scandinavia—all North Africa and most of south-eastern Asia.

Not much like the map of the last 2000 or 3000 years, that reconstructed map of the late Palæozoic Era. Yet it is difficult to put it aside as an out-worn method of accounting for geological and geographical puzzles, and the very baffling problems of how the forms of life came to be spread over the world. Geologists and geographers still cling to Gondwanaland in spite of assault by the scientists who are probing the deeps of the deepest seas. The truth is, oceanographers are more and more perplexed by this problem of the constancy, or inconstancy of oceans. The study of ocean depths does not support the theory of lost continents on the scale of Gondwanaland, stretching across vast ocean areas. Oceanographers are mainly in favour of the permanence of the ocean basins on account of " the extreme improbability that there could be such a shifting of materials in the depths of the earth's crust as would cause the sub-oceanic

[1] The lung fish is a most interesting link with Palæozoic life. In the Permian Period it existed in its present form, and millions of years ago it was able to breathe air, just as it can to-day. Living in rivers that were apt to dry up, it developed a primitive lung and thereby acquired power to survive the fickle conditions of its environment.

heaviness to give place to the sub-continental lightness ".

So the question seems to turn largely on the varying specific gravity of the earth's skin.[1] It is even suggested that the continents are actually floating on the deep-sea floor, much as icebergs float on the sea, and nearly in the same relationship of specific gravity. You see how the isostatic balance mentioned on page 19 comes into it. *Terra firma* is only relatively firm. Every time the tide comes in, the shore sinks a few inches under the weight of the water; every time the tide recedes the land uprises again. Exact measurements in the English Channel have shown that the sea-bed heaves, rising and falling as the tide ebbs and flows; not much, but enough to show how surprisingly elastic is our altogether surprising lithosphere.

But as to those strange fossil forerunners of the life of to-day, for which the land-bridges were thought necessary —can their world-migrations be accounted for in any other way? Not easily, it must be confessed, but there are possible explanations. What if they spread from what are *now* polar regions southwards along the three south-trending continents? It is not incredible, if we remember how climate has changed, bringing glacial periods nearly to the equator. There was a short time—short in the age-long, often interrupted spread of genera and species—when lions, tigers, hippopotami, roamed northern Europe. Whether we assume a shifting of the Poles—a change in the axis of the earth's rotation—or whatever hypothesis seems most probable, we cannot get over the fact that tropical corals once made reefs in seas that are now ice-cold.

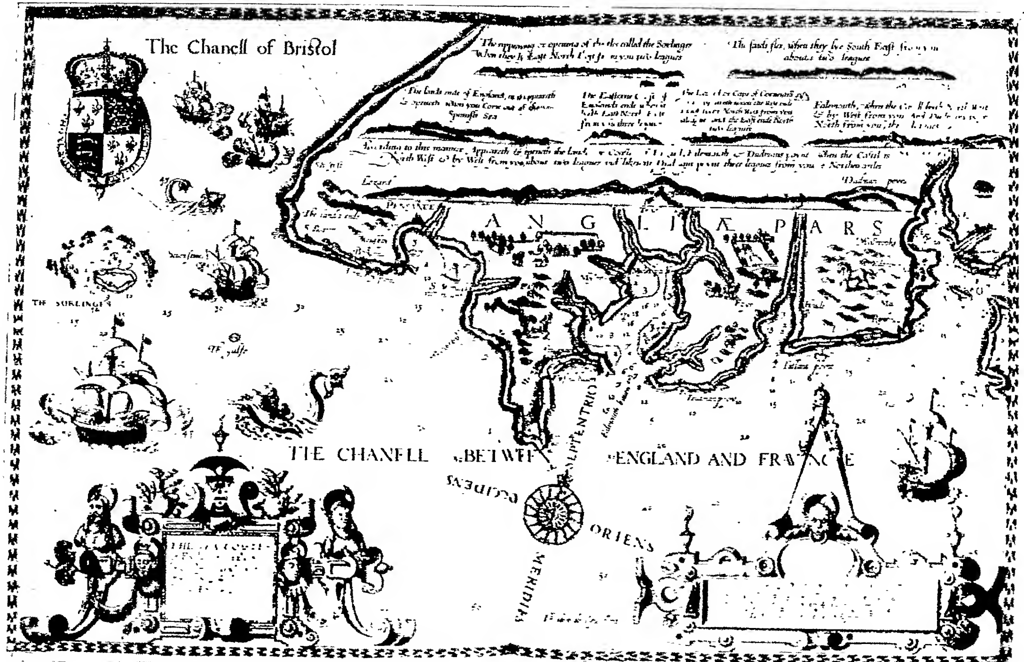
[1] The average specific gravity of the continental masses has been found to be 2·6. The average specific gravity of the deep-sea floor is 2·9, the same as the heaviest kind of granite.

CHAPTER III

Sages at Sea

Some of my readers, perhaps, may have read of Anaximander, who, as Professor of Physics and Mathematics in a Greek university some little time ago—a trifle of 2500 years—was remarkable for the expression of some rather startling views. As, that the sun was a cylinder, twenty-eight times the size of the earth, from the open ends of which flowed streams of perpetual fire; and that the earth was another cylinder that had been made by the drying-up of moisture by the sun. He propounded as well a highly ingenious theory to account for the phenomena of matter and the origin of the world; and although he did not get so near the truth as did his less agreeably named successor Anaxagoras, a century or so later, his conclusions were original and stimulating. But Anaximander lives for ever, not for his cosmogony or his physics, but because history and tradition name him the inventor of maps.

Yet we need not subscribe too dutifully to the accepted tradition of Anaximander and the first map, because we cannot suppose that the adventurers and navigators who preceded his generation by thousands of years went mapless. Every intelligent race that ever went a-roaming over land and sea has used maps—of sorts. Primitive races of our own times certainly possess them—Lapps and Eskimos, Dyaks and South Sea Islanders. Remember that Montezuma presented Cortes with a map of the Mexican Gulf coast. And if you object that Montezuma was not of a



E 325

A SIXTEENTH-CENTURY SEA CHART

A map of "The Sea Coastes of England" taken from Wagenaar's book, *The Mariners' Mirror*, published in 1588

Facing page 32.

primitive race, I offer you Tupaya the Tahitian, whom Captain Cook brought to England in the *Endeavour*. He had maps.

The Babylonians were great map-makers and plan-makers, and we have their map-tablets of baked clay of a period nearly 2000 years before the time of Anaximander. Yet they did not venture to show the whole world, as he did; none at least have survived, so that if any facetious cartographer of ancient Babylonia ever drew a world map it was probably destroyed forthwith as a rather unseemly joke. One suspects the sense of humour, that extremity of imagination, to have been left out of that serious, pragmatic people. But Anaximander, asked for a world-map, entered at once into the spirit of the request. In the very middle of his famous map he put his own Ægean Sea; to the right extreme of it, the Caspian. And then, as the left side looked bare, he sought a master mariner. "What about the Tin Islands?" said the master mariner. So they were put in, to the west, and a few parallels for finish. "Behold!" said Anaximander with a flourish, "I have shown the world!"

Two or three hundred years later scientists were sneering at the crude notions of their predecessors. They considered Anaximander's map, and "Pooh!" they said, "That's all wrong. We'll change it." They did. The maps of 200 to 100 B.C. revealed the inhabited world as a rough triangle of land entirely surrounded by water. The great Ptolemy of Alexandria, even, was not much nearer the truth in spite of his famous geography book in eight volumes. By Ptolemy's time—A.D. 150 was the date of his geography—scientific men had assumed the earth to be a sphere. Consequently, Ptolemy's maps gave latitude and longitude, but as he based his longitude from the Canaries, as being the most westerly point on the world, and his parallels of latitude on Rhodes, as being the most central, calculations of distance must

have given rise to some very strange results. However, Ptolemy's maps, and the system on which they were based, were vastly superior to those that followed a thousand years later. Most of the maps of the early Middle Ages were altogether devoid of embarrassing trifles such as meridians of longitude and parallels of latitude. There was in them no possible means of calculating distance or direction — no scale, even. The east was very generally put to the north. But to counteract such slight deficiencies and defects there was a wealth of detailed information that more than atoned for vagueness about actual places. There were castles and men and horses, dragons, monsters, mermaids, trees, and birds and beasts, both natural and supernatural. And cherubs blew winds upon them from so many points of the compass that the seas were whipped to fury.

Yes, they were bad maps—as maps. But because they touched imagination in so many places, they had in them a power to thrill that our careful accuracy, I fear, must lack. One must not forget the forces, political, economic, commercial—what you will—that set men a-roving on the Seven Seas—such forces as sent Columbus westwards to find a new trade route to the Indies. But one may be sure that there was a magic lure in those preposterous old maps—dragons and sea-monsters calling from the unknown mysterious lands and seas beyond friendly walls and familiar shores—that must have drawn a mighty band of men ardent for adventure over the seas and far away. So the world grew for us; and in growing larger and ever richer and more spacious, grew poorer too. For have we not lost, in our lust for exact distances and infinite measurements, some human function, some sense grown atrophied down the centuries, that was fitly expressed in the embellishments of those imaginative old map-makers? A dragon, a castle, a sea-serpent, and—*terra incognita.*

What did they think of the sea, those brave old voyagers of the vanished centuries? As to the veritable pioneers, whoever they were, and wherever they ventured forth, we have no possible means of knowing; we can only guess, with the help of our own sensations and emotions. Records there are none. But the art of shipbuilding was well out of its crude and callow youth by the time the Phœnician city of Tyre waxed great. The early Egyptian ships of the second civilization reveal a standard of design and construction that was obviously the outcome of many centuries of progress. There have been deep-water seamen of the Persian Gulf and the Indian Ocean for 10,000 years or more, and although the Phœnicians are the only people of those shores who made a mark on history, doubtless there were other races of seafaring tradition. Ships there were of skin, and ships of sewn bark, and ships of planks and ribs and keelsons. The boldest of the coastal men had ships, all the world over, thousands and thousands of years ago. Picture the ships of the ages—a pageant of enterprise! And fair or foul the ventures that steer the procession—commerce, plunder, or battle, or the urge that sets men a-roving for no gain but love of adventure, there was no captain in all the fleets but was under the spell of the ocean's magic. And a most unkind sort of magic they made of it—sinister, inimical, terrifying with the terror of the unknown.

That was what they thought of the sea. Surprisingly little has come down to us in narratives of really great voyages before the Christian Era. There is the famous enterprise of Necho or Niku, King of Egypt, from 610 to 594 B.C., who sent a fleet, manned by Phœnician seamen, round Africa. Down the east coast of Africa they sailed by way of the Indian Ocean into the Southern Ocean. When autumn came, these sailormen became farmers. They went ashore, sowed a bit of land with corn, lived beside

it until it was fit to reap, and then set sail again. So two years went by, as they went round the Cape and up the west coast of Africa, and the third year they entered the Mediterranean again through the Straits of Gibraltar. Herodotus told the story with scepticism, because, says he, "on their return they declared—I for my part do not believe them, but perhaps others may—that in sailing round Lybia (Africa) they had the sun upon their right hand." Perhaps we may consider that fact the best evidence that such a voyage was really accomplished.

It is hard to believe, but it is none the less a fact, that interest in the sea, as a natural phenomenon, as an integral and very remarkable part of our world, is a growth almost of our own times. The ancients frankly confessed their dismay; and later peoples, except the few constantly in touch with it, have regarded the ocean with misgivings and disapproval. The obstructive, disagreeable sea was a force with which man had no more dealings than he was obliged. And in olden days no mariner ever went out of sight of land if he could help it. He hugged the coast, often to his greater danger, for all he was worth. Of course, after Vasco da Gama, Columbus, and Magellan—after the known world had been practically doubled—the ocean took on a different proportion in men's minds. The crowded thirty years from 1492 to 1522 inevitably led to a new outlook; but knowledge of the sea and interest in it were alike entirely superficial until the nineteenth century.

I have said that maps of some sort or another have accompanied human progress from times of remotest antiquity. Such does not seem to have been the case with sea-maps, or charts, perhaps because ancient mariners disdained their help; more probably because they could not have been really helpful without reliable means for taking bearings. There were no charts until the thirteenth century, say a

hundred years after the coming of the magnetic compass. For long after that ship-masters seem to have got along very comfortably without such aids to navigation, except perhaps in the Mediterranean Sea, where marine transport was most highly developed. The ships of the Middle Ages hugged the shores from the sense of security that came from knowing more or less where they were. Mariners naturally developed an astonishing bump of locality; their memories became charged with an unwieldy mass of in-shore data, that in time became traditional. They *knew*, as from a sixth sense, the prevailing winds and currents of familiar coasts, the shoals and bars, safe and dangerous anchorages, and so forth. They had a nose for good shelter in dirty weather, and faith in their anchors to give security in foggy. They often got lost, and turned up in unexpected places.

A fact that emerges from sixteenth century sea-records is the mutual helpfulness of seamen of all nations. Although at that time piracy began to cast its shadow over peaceful shipping, it was not then, except perhaps in the Mediterranean, the bane it afterwards became—a peril out-doing all natural sea perils. It was then customary for ships—except as between nations at war—to speak each other for friendly intercourse and the exchange of useful information. In that way, ships doubtful of their whereabouts found themselves again. There would be exchanges of presents, mutual felicitations and partings in perfect amity. All voyages of exploration, such as were undertaken from desire of venturers to find new trade channels (and there was then no exploration for its own sake) depended largely upon local help and guidance. The master of the "Pinesse called the *Serchthrift*", sent by the Muscovy Company in 1556 to discover a route to the White Sea by way of North Cape and Nova Zembla, would seem to have been a rare

fellow at getting something for nothing. He was always in want of direction from craft native to those cold northern seas, and his knack of making friends got him out of a hundred difficulties. His narrative is perfectly frank. There are many references to local craft which "came aboord of us"—generally with substantial presents; "a great loafe of bread, and six ringes of bread which they call Colaches, and four dryed pikes and a peck of fine oatmeale". By way of return, "I gave unto the Master of the boate, a combe and a small glasse". To my way of thinking Master Steven Burrough of the *Serchthrift* was inclined to stinginess. His return sounds inadequate, if we consider the pumping to which he was wont to subject his visitors. But they, presumably, were satisfied with the comb and the small glass, for their intercourse with the explorer persisted for months, during which the *Serchthrift* kept company with this Russian fishing fleet, moving up the coast of Norway. The *Serchthrift* had invaluable help from these fishermen, and gifts galore, even a cable and "anker"—which were lost. But except for occasional junketings ("banketing" is the grander word in the narrative I quote) in which dried figs were the most elegant dish, the generous gestures came almost entirely from the visitors. But one can't judge. Values were different. A comb and a small glass are worth a good deal—if you happen to want them. I have only referred to this sixteenth century voyage because it is typical of so many that point to sea friendliness as aiding navigation.

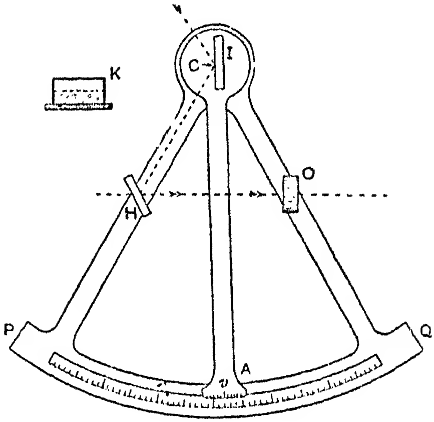
Feeling their way about strange coastal waters with the lead, and sometimes logging their soundings for the benefit of those who might wish to follow, the early rovers sailed up and down the continents. Crossing great breadths of ocean was a very different matter. Magellan tried to take soundings after he had sailed into the Pacific, and because his short lead-line could not reach the bottom, he thought

he had found the deepest part of the ocean; on the face of it a rash assumption! That typical rashness cost him his life only a few months later.

Yet we must not assume that once mediæval seamen were out of sight of land they were virtually lost to all idea of whereabouts. I suppose that any reasonably intelligent country cousin who happened to find himself afloat, alone and out of reach of land, would have enough knowledge of the stars to be able to form from them a good general notion of whither he was travelling. And if you come to wander far from home, you take good care to make friends with Polaris, as the ancients did. The shipping of twelve hundred years sailed by the astrolabe, the Greek instrument that " read " the stars less futilely for mariners than for astrologers. By that simple and ingenious device—a sphere projected on a plane, with sights and a graduated scale—the star altitudes could be taken easily, if not very accurately. For taking the altitude of the sun, they had a cross-staff, the forerunner of the sextant, which was not invented until 1730. With such primitive instruments and a lead-line for sounding and a log for calculating speed, the ships of old could not have been so completely " at sea " as I may have led you to suppose. Skippers probably knew where they were—within a margin of error of a few hundred miles!

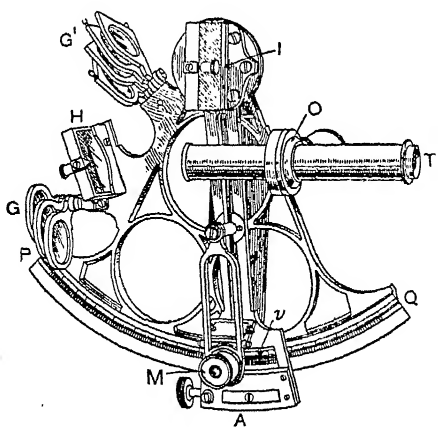
It is a fairly easy matter to determine a ship's latitude, either by taking the altitude of a fixed star or of the sun at noon. If you have ever ventured into optics, you will remember that a ray of light twice reflected makes, with the ray before reflection, an angle equal to twice the angle of inclination made by the reflecting surfaces. That is the principle of the sextant, which is so called because the instrument is in the form of a sector which is a sixth part of a circle. The sector is graduated, and has moving on it a limb carrying a mirror at its pivoted end. Another mirror

is fixed vertically to the sector, and there is also fixed to it a little telescope through which the observer "takes" the sun. He puts his eye to the telescope and looks at the orb through a little slit in the fixed mirror; then he moves the sliding limb until the reflection of a *fixed* object—the horizon—thrown from the movable mirror upon the fixed mirror, comes into line with the sun seen through the telescope. He is then able to read off the angle between them from a scale on the sector.



Simplified view of Sextant
Dotted lines indicate lines of sight.

Thus he knows the angle at which the sun is highest above the horizon; and if he knows as well—as he does from tables provided for his use—the angle at which the sun is at that time above the equator, he can easily calculate how far north or south of the equator he is.



Construction of Sextant
G, G[1] are shade glasses for use in observing the sun.
M is a magnifying glass for use in reading the vernier.

In the diagram on the right the sextant

is seen to consist of a sector of a circle PQ, rather more than a sixth of the circumference (whence the name sextant). Pivoted at C, the centre of the circle, is a brass index-arm IA, with a vernier *v* at its outer end. Mounted rigidly at C on this arm, with its face perpendicular to the plane of the circle and in the centre-line of IA, is a plane mirror I, called the index-glass. The vernier moves along the scale of angles engraved on PQ. The scale is numbered from Q towards P from 0° to 120° or farther. H is another plane mirror facing O, with only the lower half silvered, as shown in elevation at K. This is called the horizon-glass, and is fixed so as to be parallel to I when the vernier is at zero. At O is a ring into which a telescope may be fixed. When the altitude of a star is to be taken the sextant is held vertically, and the arm IA turned until the image of the star, formed by successive reflections from I and H, is seen on the horizon, which is visible through the unsilvered part of H.

But to find the longitude of any place is another story altogether. For in this case the mariner requires to know the difference in time between two places. Before he can determine his position at any point east or west of Greenwich he must know, when it is noon with him, what o'clock it is at Greenwich. In other words, he must keep Greenwich time, wherever he goes. As you may imagine, that was an impossibility in the days before accurate watchmaking. And when you reflect that there was no such thing as an accurate timekeeper until the eighteenth century, the achievements of the early navigators may well acquire a new interest for you.

Remember that the earth revolves through a degree of longitude—that is sixty miles at the equator—in four minutes [1].

[1] These are nautical or geographical miles, equal to 1·151 "statute" miles—the sort used on our maps and mile-posts—of which 69·12 go to a degree. The geographical mile is thus one minute of arc of the equator —a sixtieth part of a degree; while the mile we recognize in our walks and drives is a measure fixed for us by law in the reign of Elizabeth.

For every degree of longitude east of Greenwich, local time on the equator is four minutes before Greenwich mean time; for every degree west, four minutes behind Greenwich mean time. So that if a ship's clock is two minutes out of true Greenwich time, the ship is inevitably out of its reckoning by half a degree—thirty miles. On a very long voyage the miscalculation can easily amount to hundreds of miles, for the discrepancy is increased with each observation. Of course, the measure of a degree of longitude diminishes north and south of the equator, since the meridians converge at the poles. At Land's End, which almost touches 50° N. latitude, a degree of longitude is only 44·35 English miles; and at 56° N., just above Edinburgh, the interval has diminished to 38·58 English miles.

It was a Yorkshireman named John Harrison who rescued navigation from the disastrous risks which beset it for want of an instrument that could record accurate time. Harrison was born at Foulby in 1693, the son of a carpenter. As a boy he developed an amazing bent for mechanics and especially for watchmaking, yet he remained an unlettered and inarticulate genius to the end of his days. By the time he was twenty-one an Act of Parliament had been passed offering rewards severally of £10,000, £15,000, and £20,000 for the discovery of a means of determining the longitude at sea within sixty, forty, and thirty miles respectively; a most emphatic indication of the urgency of the need! Harrison determined to compete, as, of course, did many another watchmaker, for the prize was open to the world. After years of experiment he produced a chronometer that was tested on a naval vessel on a cruise to Lisbon and back. The chronometer survived the test. The captain signed a certificate in which he admitted that his reckoning was more than sixty miles out (in a voyage of 1400 miles) according to Harrison's "machine" as he called it. "When we made land", the captain wrote, "the

said land, according to my reckoning (and of others) ought to have been the Start, but before we knew what land it was, John Harrison declared to me and the rest of the ship's company that, according to his observations with his machine it ought to be the Lizard—the which, indeed, it proved to be—his observation showing us to be more west than my reckoning, above one degree and twenty-six miles."

You might suppose that Harrison gained the prize. So he did, but not until he was a very old man, impoverished and embittered by the perfidy of a Government that unjustly withheld it from him, on one specious excuse or another, for nearly forty years. He made chronometer after chronometer, each better than the one before, and all came triumphantly through Admiralty tests on long and stormy voyages. He was undoubtedly entitled to the award of £20,000 for discovering a means of determining longitude within an error of thirty miles. Perhaps it is best to turn over quickly the shameful page of our national history that records the shilly-shallying of the ministers of Harrison's unhappy days.

We have spent some time in looking backwards at the dawn of sea knowledge and experience. Perhaps we needn't seek too much to avoid the echoes that come up from the sea. Valiant vanished ships of the adventurous yesterdays—of strange poetic names of burning memory—manned, if we would go by likelihood, not by the heroes of legend and story, and yet, in retrospect, by men partly heroic; cruel, crafty, self-seeking, self-indulgent; yet childlike in faith, enduring in hardship, patient in suffering. In one word, brave. Who can resist their ever-living murmur from the thrilling waters? Not I, for one; and so I give you warning!

Exploration of the seas, the slow mapping of the world under the continual stimulus of commerce led, in time, to the making of sea-maps. And it was the making of sea-maps in modern times, on accurate and systematic lines that

would have astonished mariners of no more than 200 years ago, that stimulated interest in the mysteries of the sea-floor. The modern chart-makers are a fitting introduction to our story of the sea, for it was they who founded the fascinating and very modern science of oceanography. You may think it odd that so many centuries of sea wisdom should have slipped by before the wisdom became incorporated in a science, since the ranks of seamen included many able and inquiring men in the seventeenth and eighteenth centuries.

As for charts, they are not such dull things for landsmen as you might suppose. I am not sure, to begin with, that a chart does not typify that universal *desideratum*, something for nothing, or at least something for a good deal less than it costs. To a British taxpayer there is humour in the notion of a great public department giving something away. If the principle extended to the Post Office, say, the joke might well become one of immense popular appreciation. At present, however, it is confined to a little private jest between the Admiralty and the men of the sea. The Admiralty makes the charts and sells them at a nominal price. Nearly all other maritime countries follow the same principle; the idea being, of course, that it is the duty of a nation to do all that is reasonably possible to protect its subjects, whether afloat or ashore. Whatever makes for safety of navigation indirectly " pays its way "—to put the matter on its lowest and most materialistic basis.

Whoever suggested that charts are dull, deserves a terrible fate. If not " something lingering—with boiling oil in it ", at least a lengthy cruise, without a chart, in dangerous waters in dirty weather. He would then have to make so many soundings on his own account that he would come to realize a little of the interest of chart-making. Consider what they are—contour-maps of the sea-bottom, with thousands of

little figures giving the depths in fathoms.[1] A coastal chart has to reveal whatever of the land itself is likely to be recognizable to a ship at sea, but the essentials are the things that can't be seen; they can only be felt—with a lead-line. All the visible things must be there, lightships, lighthouses, beacons, buoys—whatever there is to see; so must the invisible things. Every rock, every shoal, every sandbank, every channel—the pilot must know them all. But the chart-maker (hydrographer, i.e. water-writer, is his horrible name for himself) has to find his contours with a lump of lead on the end of a piece of string. We may perhaps imagine him casting envious eyes on the land surveyor's theodolites and azimuths, but as they are of no possible use to him, he just gets on with the job of heaving the lead.

So many thousands of soundings go to the making of charts that a sort of mental paralysis creeps upon me at the mere thought of the immensity of the task of making under-water maps. Foot by foot, almost, they have literally to feel for the ups and downs of the bottom beneath their keels, the little surveying ships of the Admiralty Hydrographical Department. Give a thought to the extent of the British coast-line, to the narrow, crowded, crooked water lanes and straits and channels; start with the idea that it falls to *your* wits and labours to make complete, exact, and infallible maps of the bottom of the English Channel, the North Sea, and the Irish Sea—just to get your hand in; and I think you will be prepared to do honour to the little-known branch of the Royal Navy to which the sea-surveying falls. Without fuss or flurry, blowing their own trumpets only when they are fog-bound, the little ships go up and down the Seven Seas—Hong-Kong, Bahamas, or Bristol Channel—making new charts, correcting old ones. The sea-floor has an incon-

[1] On large-scale charts of harbours and very complicated channels the depths are generally shown in feet.

siderate habit of changing—to-day's fairway may be a shoal next year—and the surveying ships are always at work—sounding, sounding, sounding. Who says monotonous? Only he who never went to sea!

If you have read Captain Cook's voyages, or the records of Arctic and Antarctic exploration since the voyage of Sir John Ross in 1818, you will have come across occasional attempts to read and know the meaning of cause and effect of marine phenomena. But they seem to have been but half-hearted attempts. The most splendid secrets of the sea and of the manner in which its wonderful rhythms affect us land-dwellers in many strange and unexpected ways have been unlocked mainly at the bidding of the nineteenth century chart-makers. They revealed enough to make it worth the while of trained scientists—physicists, naturalists, biologists, to go a-roving in floating laboratories, inspired by a new and far more serious and earnest mood. We owe to the little hydrographical ships of the early nineteenth century far more than the actual charts they were commissioned to make.

In the wake of the survey ships went the cable ships. It was a great idea to be able to communicate quickly with distant peoples—but, well, the doubts, the scoffings, the incredulity—all the obstructionist absurdities of our delightful Victorian Age. The Channel telegraph cable went down fairly easily, but then the Channel bottom was nearly as well known as the hills at home. It is true some Boulogne fishermen fished the cable up again the next day and spoilt it, but that was an interlude. The Atlantic cable was a very different proposition. And all the earth was soon to become encircled. What better spur could there have been to sea investigation? But we must not forget Admiral Maury.

Mathew Maury, an American, was an enthusiast. I do not know when he first went to sea, but before he died, in 1873, he had done a vast deal to stimulate the systematic study of

ocean. "This beautiful and elevating science," he calls it, and whoever reads his books (there are not many, nowadays, I fear, for they are very much out of date) is made to feel that, for him, ocean possessed magic charm and absorbing interest. Maury's theory was that a better understanding of the sea was necessary to the more rapid growth of shipping; he worked, remember, at a period when ocean transport was growing by leaps and bounds. To him it seemed impossible for one enthusiast like himself, or for isolated groups of investigators, to make sufficient observations to provide data complete enough to base conclusions on. Yet every master mariner, he saw, was a potential bearer of the observations Maury thought most important—the drift of currents and direction of winds on definite sea-routes. Captains accustomed to those routes knew the probable conditions for their voyages at different seasons and could check them. But, he argued, there were always fresh captains sailing those ways for the first time, unprepared, untried; perhaps over-anxious, perhaps over-reckless. To understand sea laws was to foretell behaviour at sea. With the help of the United States government he inaugurated a most useful scheme. Ships' captains were encouraged to send him, at the end of a voyage, in specified form, all sorts of relevant data from their logs. In return the captains obtained free charts. Maury thus collected a mass of very important oceanographical data. It was mostly superficial, it is true—tides, winds, currents, and so forth; but it was systematic and scientific and encouraged further sea investigation from different approaches. It had too, a very important corollary in the International Commission which met in Brussels in 1853, at the invitation of the United States, and decided on uniform observations at sea, on Maury's plan. His book, *The Physical Geography of the Sea and its Meteorology*, is famous and, what is more important, worth reading in spite of old age.

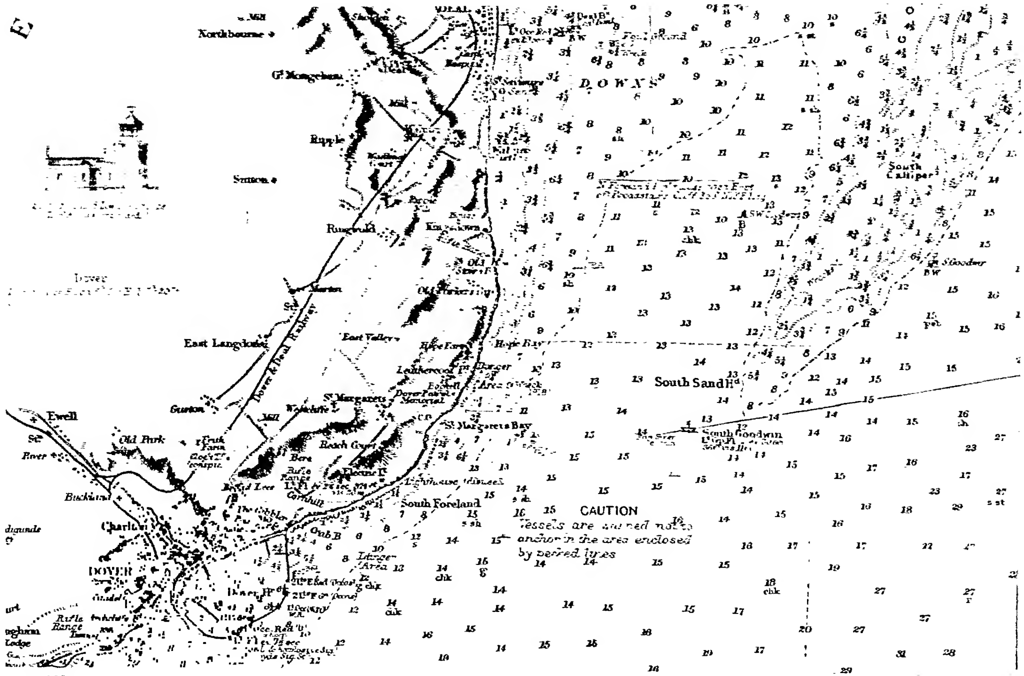
CHAPTER IV

The Edge of the Ocean

If the day should ever come when science provides for us the means to venture under water in safety and comfort, what prospects of new enterprise would open themselves to the purveyors of seaside entertainment! Can you not see the holiday-makers at some too crowded, over-popular bathing resort " queuing-up " before this notice: " Diving Helmet, 6*d*. extra "? just as they do now, poor beggars of the right to sea-room, all the long summer's day, before a mere " Bathing Tickets 6*d*., including costume ".

Those diving helmets will have to come soon—a new experience for everyone—the whole family exploring the delights and wonders of a hidden world. There's a new thrill for you! I am not romancing; it is really quite practicable, and I am not sure that the seaside resort people are not rather behind the times. Or how would you enjoy a trip along the bottom in a glass-sided submarine? I can foresee a great vogue for such a contrivance, a rush for seats that might well alarm the motor-boat proprietors and put the speed-boat fiends out of countenance. Advertisements of this kind would appear: " Travel by Captain Nemo's Submarine Safety Saloon. Experienced Drivers. Prettiest Routes." I think Captain Nemo would become very popular.

But that is a piece of nonsense. Quite impracticable and impossible—at present. However, as I want to get you under water by some means or another, let us assume that



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PART OF AN ADMIRALTY CHART, REDUCED

The actual size of the chart is half as large again

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Facing page 49

we have thoughtfully provided ourselves with appropriate get-up for exploring the sea-bottom; oxygen helmets to give us air under water, suits of material strong enough to resist the pressures we shall suffer, and—by any miraculous means you fancy—the power to move freely. When you consider yourself sufficiently equipped, let us dive in. On second thoughts we will not dive in. We will *walk* in, with fitting dignity and ceremony, to the plaudits of an admiring concourse, on the coast of Cornwall. We will even walk as far as America.

Yet we must first of all accustom ourselves to think of a new unit of measurement; to remember that six feet make one fathom. That is easy enough. A difficulty arises, however, almost before we start to make use of it, for on what datum or level are we to base our depths? The level of the sea is constantly changing; are we to employ high-tide level, or low-tide, or something in between? All soundings are based on a "mean" of low-water at ordinary spring-tides, the tides when the water rises and recedes to the greatest extent. The depth marked on the chart is consequently the average minimum depth and so conveys to the mariner the information in which he is usually most interested; not, how deep is the water he has under him, but how shallow.

Sea-level is certainly an odd and misleading term to apply to something which is continually altering. It may possibly occur to you to wonder whether the water held on the surface of a sphere can ever be level anywhere; you may like to work out the speculation. What is more interesting, is the great difference or diversity of sea-level in different parts of the world. When ships leave continental shores for the open ocean they are literally sailing downhill, for the simple reason that the water is piled up towards such coasts by the gravitational attraction of the mountain

masses. It used to be estimated that the difference in level between the sea surface in the middle of the Indian Ocean and the sea surface about the coasts, owing to the "pull" of the Himalayas, amounted to several thousand feet. And though that figure has lately been corrected to a more modest one, don't run away with the notion that the sea is really level, like a tennis court. It is full of ups and downs —undulations vastly larger than the waves that can be seen.

As we "take off" from the shore and the green water closes about our heads we become conscious, probably for the first time, of the extraordinary extent and variety of the living things about us. The sum of life in the sea greatly exceeds the sum of life on land. The sea is alive with strange forms, some humble, some highly developed, and nowhere is it so rich as in the shallow waters from which the continents emerge. Elizabethan Spenser noted with amazement—perhaps on one of his journeys to Ireland—the fecundity of sea forms.

> "Oh, what an endless work have I in hande,
> To count the sea's abundant progeny!
> Whose fruitfulle seede farre passeth those in land,
> And also those which wonne in the azure sky."

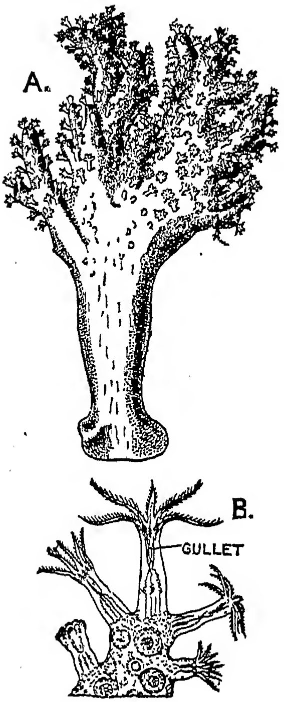
For all his insight, Spenser probably had but little idea of the profound truth of his moralizing.

Each kind of sea-bottom, rocky, gravely, sandy, or muddy, has its own peculiar category of animal and vegetable life. The shallow water which we first traverse is that of the "Continental Shelf" and the forms of life peculiar to it are known as the shallow-water *Benthos*. Benthos is the name given to all the organisms that normally have their being on or about the bottom. Many of the animals have but limited powers of locomotion, or none at all, and live permanently attached to rocks and stones, seaweeds and molluscs, or in the sand or mud. Others, though they can

move freely, do not leave the shelter and seclusion of the ground. In the upper waters dwell the creatures and plants of another category, called the *Plankton.* The Plankton drift idly with the currents, unable to help themselves; while a third class, the *Nekton,* have power to swim where they will. Nekton includes most of the fishes, both those that dwell in the upper layers of the water and those of the deep water. Those that change their levels from time to time, living sometimes in shallow water and sometimes in deep, are demersal fishes. The terms benthos, plankton, and nekton, are used to differentiate the three independent categories of life throughout the ocean, whether they are examined close to the shore or a thousand miles from it.

As we step forward on our journey we cannot resist stopping, almost at the outset, to wonder at the strange beauty of the new world. We are in a forest of lovely vegetation springing from the rocks we thread our way among. Fronds wave about us in the gentle eddies of the currents, or stir to the movement of little fish. They are of all forms, all colours. Here are the lavers, green and purple, the green not inappropriately known to sea-folk as sea-lettuce, though it looks much more like delicately tinted fabric of gossamer. The fronds of dulse are dancing rainbows; the broad blades of the oar-weed stretch high above our heads; the bladder wrack is everywhere; handsome enough its purple-brown fronds, buoyed by their bladders, and quite unlike the wind-dried rubbish we saw on the shore. There are grass-like plants that are not grasses, though the waving grass-wrack is, strangely enough, a true flowering plant; there are "sea-weeds" of feather-like form and exquisite delicacy of colouring, that are not plants at all, but zoophytes, lowly members of the animal world. And here, on the rocks and stones and on the stems of the larger seaweeds thousands of sponges are growing. A very strange form of life, indeed,

is that of the minute, jelly-like organisms, a vast host of individuals in a communal assemblage, that go to the making of a sponge. The sponges of British waters are of no commercial value; they are useless for the baby's bath—or even the car's bath, but the species are numbered by hundreds. Nor are the corals of cold seas of use to us except, perhaps, as aids to reflection; but coral polyps are to be seen in the tuft-coral, waving their tiny tentacles. Observe, too, that other polyps commonplace, the Dead Man's Toes. It looks more like a puffed-up finger of a pink glove, pierced with countless tiny pinholes. Each of these pinholes is the front door of a minute, but just visible, star-shaped polyp.



Dead Man's Toes or Fingers
A, A colony of polyps. B, Tip of a branch (magnified) showing polyps in different stages of expansion and retraction.

In and out of the weedy water lanes flash little fishes—gobies, and blennies, the pretty dragonet, the odd pipe-fish, eel-like gunnells, plaice and dabs. The Blenny is a six-inch oddment with a bull-dog head. The Goby can glue himself to a rock by means of his sucker-like fins. He is peculiar also for the "nest" he makes for the protection of his spouse's eggs; a tunnel in the sand domed with a forsaken cockle-shell smeared and sealed with a cement-like secretion. The dragonet is a dragon in miniature, handsome in lilac and yellow, his spiny fins exaggerated to look like frills and

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SCARLET SEA-SQUIRTS

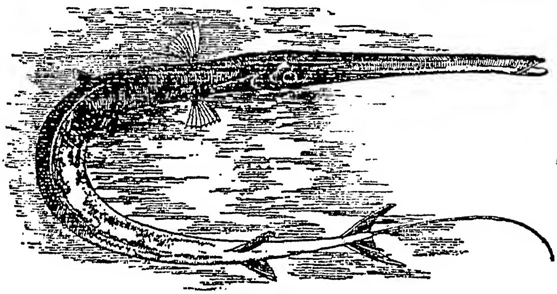
These strange figures have the scientific name of Tunicata. When young they resemble tadpoles and swim free, but as they grow they change their form and attach themselves to some fixed base.

FLOWERS OF THE SEA

The twig-like objects are feathered sea-worms. The "chrysanthemum" is a sea-anemone.

wings; while the pipe-fish is no more than fifteen inches of striped gas-tubing, with a fish tail at one end and a snake-like head at the other, terminating in a long snout, through which he has to suck in his food, for the poor fellow cannot open his jaws. Yet he obligingly carries his wife's eggs about with him in a little pouch, and it is said that baby pipe-fish seek safety in father's pouch, as baby kangaroos go to the pouches of their mammas.

A host of invertebrate animals belongs to this shallow-



Pipe-fish

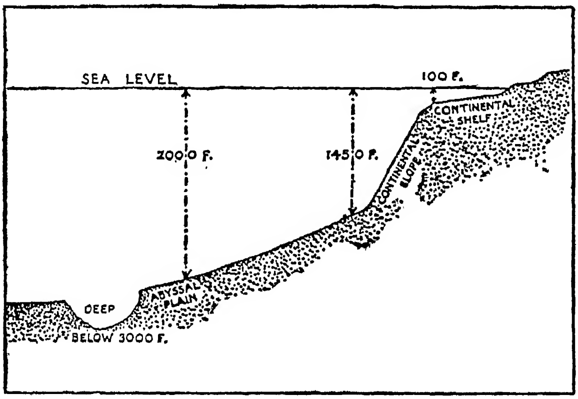
water benthos, an astonishingly luxuriant fauna confronts our progress at every step. In the sand are molluscs like the cockle and the razor. The pinna, the largest of British molluscs, lies in wait to trap little fishes in its gaping shells, half of its eighteen-inch length buried in the sand and firmly anchored there by its astonishing byssus threads. Scallops of many kinds, some with highly ornamented shells the size of a man's palm, swim through the water, their fringes of long feelers waving. On the rocks are gaudy sea-snails, cockles, and whelks in uncountable thousands. A mussel-bed stretches ahead of us in a dense blue-black mass, an animal field of many acres. We begin to realize that marine life affords an unending vista of delight, its power to interest and amuse arising from its newness, its strangeness. We

encounter fascinating functions of breathing, feeding, reproduction, of instincts and reactions of unusual and unexpected kinds. The earthworm may be quite an entertaining fellow, but he palls when we know (or think we know) all we can about him, and we may find it refreshing to turn to his more original cousins of the sea. Look at these matted tubes of sabella, a worm that makes a house of carefully selected sand grains, stuck together with a cement it makes for itself, and at the beautiful stoppered tubes of the scarlet-plumed worm, serpula. And who would suspect that the sea mice we notice as we descend to deeper water belonged to a genus of marine worms? The oval body, four to six inches long, is thickly covered with silky hairs, each one fitted with a microscopic barb, all shining with beautiful iridescence.

There is indeed a terrible temptation to linger in this green translucent fairyland. For though there is light, as yet, it is no longer the light of noon-day. Most like, perhaps, to the unveiling of the day, to the wonderful opalescence that creeps over the world at a grey dawn. We are no more than ten fathoms deep, but so quickly are the red and orange rays of sunlight absorbed by sea-water that it is impossible to proceed far without becoming aware of the strange and subtle change that comes over our visual senses. Very soon, the yellow rays will cease to penetrate; a little farther on, the green and blue. At fifty fathoms—a bare 300 feet—nearly all the white light will have gone. An unearthly bluish-violet twilight will then pervade our world, and in such gloom, growing ever deeper, must our journey proceed. At 200 to 300 fathoms deep we may be conscious that the darkness is not quite complete—a little like a starlit night but moonless; but at 400 fathoms [1] all the visible light rays

[1] Penetration of light is deeper in the tropics, the l' 't being about 500 fathoms.

will be absorbed and we shall then move in absolute darkness. The ultra-violet rays penetrate a few hundred fathoms deeper, but they, being invisible to our eyes, give us no help. This alteration in the character of the light as depth increases influences the growth and colour of the seaweeds, for sea plants, like land plants, depend on light for nutrition. Water plants—the large ones as well as the most minute—comprise the division of life called algæ, which is the Latin



word for seaweeds. They all contain chlorophyll, the green colouring matter of light-elaborated sap, but they also possess other colouring matters—blue, olive, or red, as the depth increases—which aid the vitally important chlorophyll to meet the modified influence of the light.

Our journey trends mainly downhill. But it is not altogether like a walk down a smooth hillside; there is a good deal of uphill climbing to be done, little valleys and gullies to cross. I have said that we are walking on what is called the "Continental Shelf". Below the Continental Shelf lies the "Continental Slope", for the most part much steeper in gradient, but gradually descending to the Abyssal

Plain. We shall of course approach corresponding zones as we cross to the opposite continent. When we have crossed the Abyssal Plain from east to west we must climb first the relatively steep Continental Slope of America, and then the Continental Shelf, before we emerge on the dry land again. The British Isles form an integral part of Europe. The seas that separate them from the general mainland are mere overflowings over land that has subsided or become depressed, and the sea-bottom of the Continental Shelf over which we journey retains a good deal of the irregularity of the land we have left behind, though smoothed and softened by water. We are aware of undulating stretches of sand, of gaunt rocky tables and terraces rising to form reefs, and clean and bare where they are exposed to the direct swirl of the current. Here and there are channels in slack water, where the first sand is deposited. We notice as we go deeper, that the rocks are mostly left behind, while sand becomes more and more the predominant feature of the ground under our feet.

We still tread ground that has been washed down from the dry land—fragments broken from the land and carried to sea by tidal currents. Rain and frost and wind no less than the ceaseless battering of the waves wear down our coasts, while each river adds a contribution it has stolen from the inland hills. The rocks and boulders rolled down upon the shore and snatched into the sea by the undertow of the waves come to rest not far from land; next the coarse large gravels find a resting-place, while the finer gravels are carried farther out to sea. The sandy particles are conveyed to greater depths before they settle on the bottom, the coarsest grains first, the finest and lightest floating farther out to settle in still deeper water. There remain in suspension the infinitely fine particles that form mud, which sink very slowly and are carried to great distances from shore. But

down to the bottom it all goes, ultimately, much of it being carried there not by gravity, but by the chemical action of the salts in sea-water. At a depth of fifty fathoms mud begins to predominate and at a hundred fathoms we are definitely on the " mud line ".

But here and there in these shallow waters of the Continental Shelf are patches of sea-floor that belong exclusively to the sea. For a while we tread fields of broken shells in token of her prodigality of life, an initiatory glimpse of the greater wonders to be revealed in the deeper waters. To one side of us appears a wide extent of ground composed of worm tubes, where our friend Sabella has been at work in his millions. And here and there are masses formed of the skeletons of corallines, which are not corals, though they might be from the look of them, but sea plants that clothe themselves with stony accretions of lime. And there is raining upon us all the time a rain of which our senses are quite unconscious, for it is composed of diatoms and other microscopic marvels that we must examine, but not yet awhile.

We must cross now an old river bed, down one side and up the other of a fairly wide valley. We are approaching the limit of the Continental Shelf, in 100 fathoms of water, and we shall soon have to face the steeper descent of the Continental Slope. The fish that were so plentiful in the shallower waters no longer keep us company. The crabs, the star-fishes, the shrimps, and prawns, and other invertebrates that sprawled and crawled and swam up to the 20-fathom zone have disappeared. Though there are plenty of fish around us, their kinds have changed. Soles and plaice and dabs have given ground to turbot and brill, cod and whiting to ling and hake, witch and megrim. At 50 fathoms, lobsters flashed past us, swimming backward with mighty strokes of their fan-shaped plated tails. The great feeding-grounds are those where the fine detritus

from the land, highly-charged with minute organic matter, comes to rest. Here life of all kinds is most richly represented; but because the region of the densest population is the most dangerous for the eggs and fry of fishes, many of them proceed to deeper waters at spawning time, or to greater distances from land in the case of those genera and species which spawn at the surface.

But although as we leave the region of the Continental Shelf, and exchange the shallow-water benthos for that of the Continental Slope there is a great "thinning out" of the life about us, there is still no lack of life. There are plenty of star-fishes, brittle-stars, sea-urchins, anemones, corals, and other polyps, gasteropods like whelks and snails, sea-cucumbers and sea-slugs, and similar animals that eat the mud and absorb nourishment from it. There are fish, too, including the hake, but most of the fish are beginning to exhibit quite unfamiliar features. The quaintly named "head-footed" animals, the cephalopods, seem to be increasing in size; the cuttle-fish and the huge-eyed squid give place to the common octopus. These giant molluscs, the most highly developed of invertebrates, are not pleasant companions. They are ugly brutes. The one "walking" on the bottom on bent tentacles looks more sinister than his swimming companion, though both have tentacles seven or eight feet long. He swims, you notice, in the way of his relations the cuttle-fishes and squids, by filling the double-barrelled tubes of the syphon with water and then ejecting it in two powerful squirts which drive him backwards. But if we spend too long looking at all the strange animals around us, we shall never get across the Atlantic! We must leave them for another chapter.

CHAPTER V

On the Bottom

You are to suppose that we are continuing our westward journey across the sea-floor. In the last chapter we traversed the Continental Shelf forming the rim of the mighty basin that holds the Atlantic. Let us imagine, then, that we are on the bottom, on the Continental Slope, in four or five hundred fathoms of water; but a little distance above us there is a still stranger bottom.

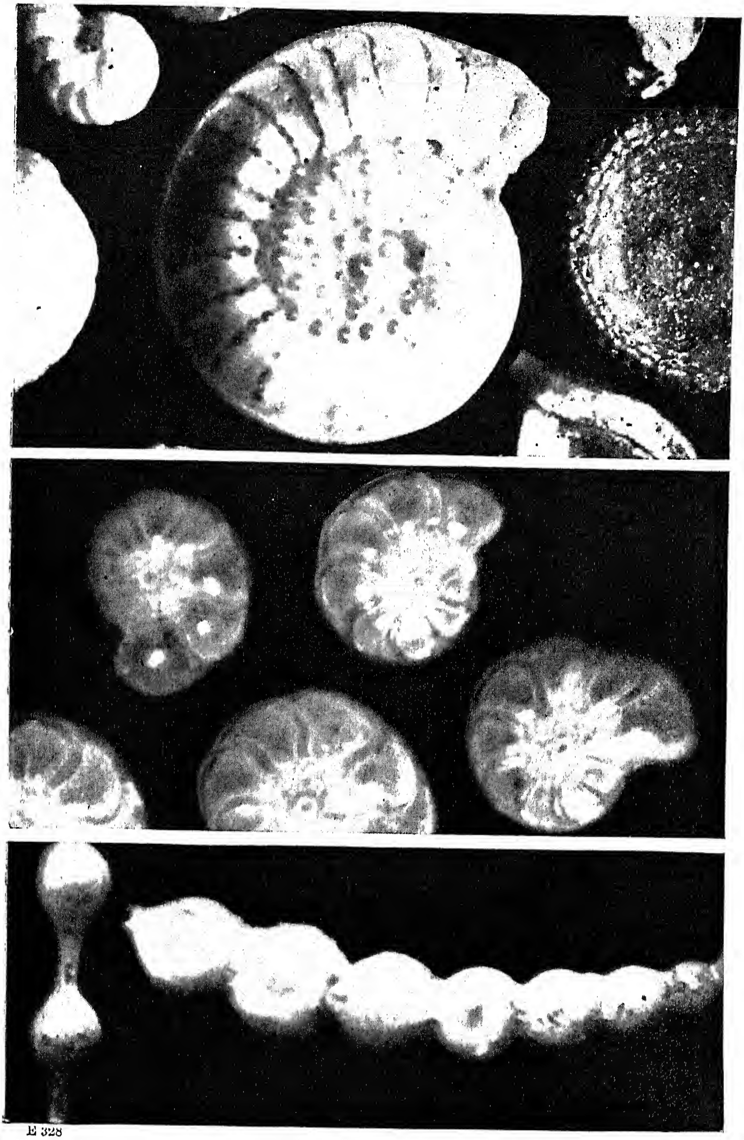
It is an artificial bottom, but none the less a very important one for the nekton, for which it provides a feeding-ground as rich as the " mud-line " we passed, you remember, a little while back. You must know that in the sea as on land there are herbivorous as well as carnivorous creatures, and that the vegetable-eaters, feeding mainly on minute algæ, in their turn are consumed by the carnivores. Now in the upper layers of the sea there is an enormous zone of life—the idly drifting plankton. The bulk of this life is composed of minute algæ, and the dead remains of this, as well as of tiny animals, form an all-pervading cloud that is constantly drifting downwards. Some of it is ultimately dissolved or split up by chemical action; a great part falls to the ocean-floor; but however far it travels, it must go through a stage at which its rate of descent is slowed up. The deep water is colder than that above it and also more salt, and it follows that its density—its specific gravity—is increased. When heat is withdrawn from a liquid the

molecules move closer together—witness the difference in viscosity of motor-oil before the engine has run and when it is warm. Therefore, where there is a marked change in the viscosity of the water, as at 200 or 300 fathoms in the North Atlantic, there is a corresponding change in the rate of descent of the food materials of the host of fishes and invertebrates forming the nekton. The cloud of organic matter raining downwards is greedily gobbled up on this " artificial bottom " where it is arrested in suspension.

Really, we must mind how we are going, for we are like enough to come to grief on the precipitous descent of the Continental Slope. While we were on the Shelf, it was rather like going down an easy hill-path; now, however, we appear to be on a mountain side and a pretty steep one at that, albeit the British Isles are set well back on the Continental Shelf. We are obliged to walk several hundred miles seawards before finding our heads covered by a thousand fathoms. If we had stepped off from the west coast of Africa in latitude 20°, we might have dipped to nearly 3000 fathoms in a much less distance.

The sea-bed has changed entirely; and although for a long while in our downward journey it has been mud, the mud itself is different. The ooze we tread is no longer of the dry land. Some of the volcanic dust it contains came from land volcanoes, and drifted in the atmosphere or in the water for years before it found a final resting-place; but most of the volcanic debris about us was expelled from submarine volcanoes. Here before us rises the dead cone of one—an enormous " dome " (as it is called) towering upwards towards the surface of the sea, yet so small, comparatively, that although its existence was discovered by sounding it was a terrible business to find it again.

All the sea-floors at distances far removed from land are covered with what are called *pelagic* deposits—all, that



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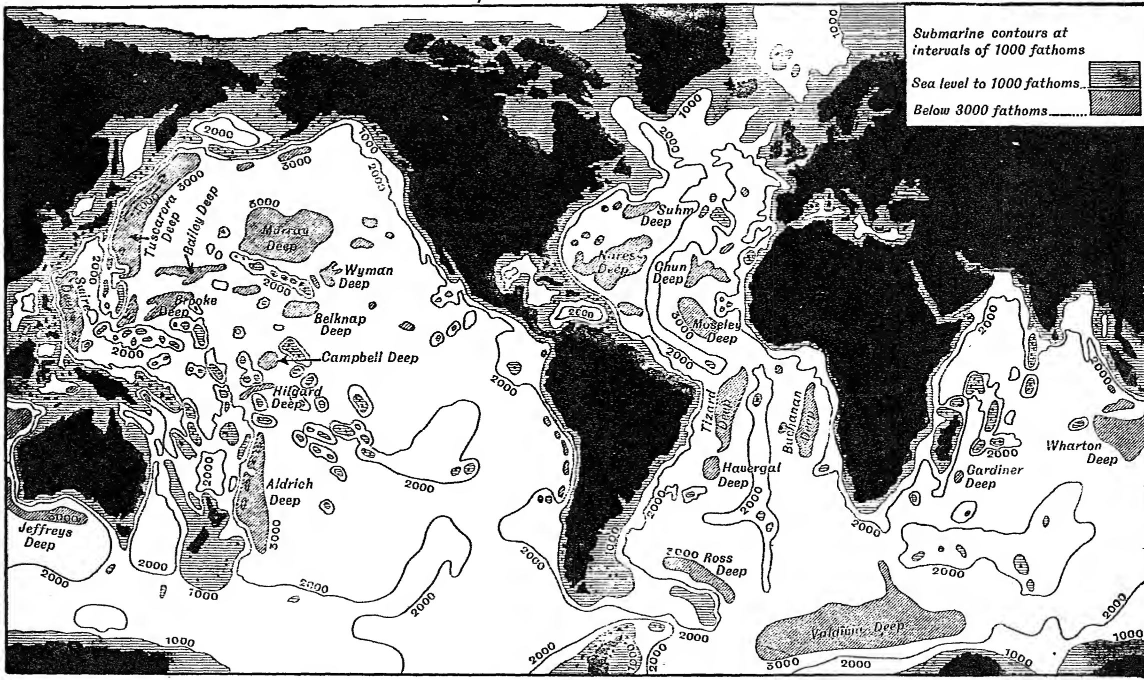
FORAMINIFERA, HIGHLY MAGNIFIED

From typical Ooze soundings (*Challenger* Expedition)

From photomicrographs by F. Martin Duncan, F.R.M.S., F.Z.S.

Facing page 60.

THE WORLD, SHOWING OCEAN DEPTHS



is, except the very greatest depths. In such depths—wherever there is 3500 fathoms or more—the predominant deposit is that known as the Red Clay. Pelagic comes from the Greek *pelagos*, meaning the deep sea; we have the same word in archipelago, and it is used to denote the deposits formed by the insoluble remains of the minute organisms of the plankton that sink to the sea-floor far away from land. The vast, downward-trending plain we contemplate, the Abyssal Plain of the North Atlantic Basin, is mostly globigerina ooze. Consider that this type of ooze covers an estimated area of some forty-eight millions of square miles; consider again the statement of telegraph engineers that it accumulates at the rate, in some places, of ten inches in a hundred years; and then reflect on what it is composed of. It is chiefly the remains of pelagic protozoa, lowly animal organisms of a genus of foraminifera.[1] These globigerina live in the upper layers of the sea; their corpses are perpetually raining down upon the bottom, a rain without end, and, one might almost say without beginning. These creatures, with limy shells often of marvellous beauty, are as grains of fine dust in size. Four million individuals might not make an ounce of that dust, yet they made the chalk cliffs and downs of England, and their close relations, of one genus and another, raised the Alps and provided the stone for the Pyramids. They have been earth-building for uncountable centuries. We have no possible means of knowing how deep is the globigerina ooze in the bed of the Atlantic, but there is surely something humbling in the thought of those forty million square miles of sea-floor, and of the great thicknesses of limestone rocks that were secreted from oceans of the dim past by creatures invisible, but rivalling the grains of sand in multitude.

Another form of pelagic protozoa, also with limy shells,

[1] Latin, *forare*, to pierce; i.e. protozoa with perforated shells.

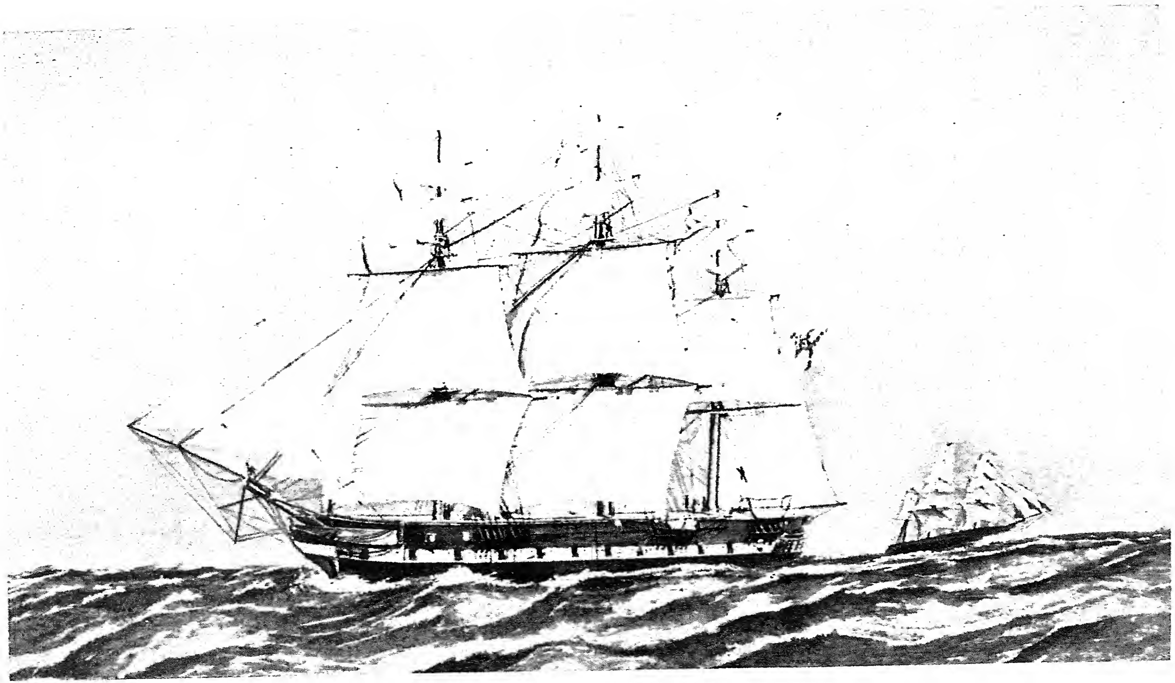
like those of globigerina, is abundant in the warmer seas; but these—the pteropods—have a much narrower distribution, and the ooze formed of their shells covers no more than a paltry half-million square miles. Far more numerous than the pteropods are the radiolarians, far more beautiful in structure than the globigerina, and differing from them in the composition of their hard parts. Radiolaria do not have shells of lime but a sort of skeleton of silica. These marine protozoa, of which there are many species, are so small that eight millions of one sort can live together and move and function in a single cubic inch of water. The flinty framework they make for themselves is like an exquisite lace of glass; their jelly-like bodies put out feelers to search for food. They are born and they die, like all these marine microorganisms, in multitudes that must be measured in billions a minute. Their remains form the characteristic ooze over an area of about two million square miles, mostly in the Pacific and Indian Oceans. They are only found where the depth is about 3000 fathoms. And that is rather queer, for they are organisms of the surface and are distributed over a wide area of ocean in warm latitudes, shallow as well as deep. The reason radiolarian ooze is only found in quantity in waters three miles deep is that in such depths there are no limy shells to overwhelm and obscure them; they have survived depths that no other organic remains can approach. There are no foraminifera at a depth below 2500 fathoms, except in the North Atlantic, because calcium carbonate is dissolved at greater depths.

Greater in its extent than that of the pelagic radiolarians is the diatom ooze, which covers about ten million square miles in the great Southern and Antarctic Oceans, forming a nearly continuous band around the Antarctic continent. These organisms have flinty shells, but they are not protozoa, not animals, but algæ, and moreover, algæ of extraordinary

interest. If you are a microscopist, or any variety of experimental biologist, you do not need to be told what diatoms are. But the uninformed may imagine a simple vegetable cell (if he can!) divided into two halves by a transverse membrane. Imagine, next, the outer walls of the two halves of the cell becoming coated with glass and fitting one over the other, somewhat as the lid fits over an oblong or oval box. Decorate this glass lid with wonderful striated patterns and give to it the power of movement and you have a fair idea of a diatom.

We must tread nearly two thousand miles of globigerina ooze in our journey under the North Atlantic, a most strange and dreary journey across a seemingly unending plain. The slopes downward to greater depths than two thousand five hundred fathoms, and the ascents to the waters of less than two thousand fathoms, are so gradual that they are quite imperceptible. What are a thousand fathoms—6000 feet—a mile in a thousand miles? Here and there is a submarine "dome", an old volcano such as we encountered before, rising steeply from the level floor. Though we have to cross a submerged plateau, here called the Dolphin Rise, we are quite unaware of the climb up to it, yet it brings us within 1700 fathoms of the surface. It is part of an S-shaped ridge running through the central line of the Atlantic basin; there is a break at the equator and then the ridge continues as a plateau almost due north and south beyond 50°.

Absolute darkness, absolute stillness, only the slowest current stirring in these dreadful depths. The temperature is but a degree or two above freezing, and below 1000 fathoms it never varies, or so slightly as to be unnoticeable. We have long since passed the depths at which seasonal variations—summer and winter, sunshine and mist—may have changed the temper of the upper waters, just as we have long since passed the last vestiges of plant life. The seaweeds were left



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H.M.S. *CHALLENGER*

Reproduced, by permission, from a painting in the possession of The Challenger Society

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behind at the lower limit of what is called the photic zone—the region of light penetration—and now, all there is to remind us of the vegetable world is the invisible rain of dead diatoms. But strangest of all and hardest to realize is the weight of the water. For every five fathoms we have descended the pressure has increased by one atmosphere until, at a depth of between two and three thousand fathoms, it presses upon every surface with a weight of between two and three tons to the square inch. And yet—marvel of marvels—this strange world is a living world, peopled by creatures breathing, feeding, increasing; stirred to mysterious ends by the same vital cell-substance called protoplasm as that of the sunny fields and hills of home. Spectral shapes float past us, of the blind luminous abyssal fishes; there are red crustaceans with long legs, molluscs, sponges, star-fishes, sea-urchins, sea-pens—almost all the forms we know are represented. "There can be no life in the great deeps," said the unwise prophets of a few generations ago. "There are no deeps without life," answer the marine zoologists of our own time.

Our journey over the grey semi-liquid ooze is nearly done. We are approaching the Continental Shelf of America. But before we climb the terraced precipices that lead gradually to daylight, let us turn south awhile, that we may venture into one of the ocean "Deeps"—a depression over 3000 fathoms. Although, taking the average for all the oceans, the area where the water is over 3000 fathoms is in a very small proportion—about 7% compared with 58% between 2000 and 3000 fathoms, the typical material of these very deep bottoms covers a very great area of the sea floor—some fifty million square miles. This material is known as the Red Clay and in some ways it is even more interesting than the organic oozes. It is exceedingly fine red or reddish-brown ud, made up partly of silicates of lime and alumina and

oxides of iron and manganese, partly of volcanic remains. Some of the volcanic dust came from the atmosphere, but most of it must have originated in submarine volcanoes.

Mixed with the volcanic debris of the Red Clay is matter from outer space. This matter is mostly cosmic dust, a product of the combustion of meteorites from friction with the earth's atmosphere, but large quantities of "cosmic spherules" are also found in it, that is, larger lumps of meteorites. These lumps are generally of magnetic iron and nickel, but there are others called "chrondres" which are of no known earthly substance, and form a crystalline material only found in meteorites. It is not, perhaps, generally known that so far from being an unusual phenomenon, meteorites fall upon the atmosphere in a ceaseless rain. The earth's orbit appears to cut across the path of a gigantic elliptical ring of meteors, the remnants, perhaps, of a meteoric nebula from which the solar system was formed. Anyhow, some hundreds of millions of little visitors from inter-stellar space are pulled to earth every twenty-four hours. Perhaps twenty million of them can be seen for a moment as shooting stars; and though, by the time they reach the lithosphere, most of them have been burnt up to a fine dust, some of them are large enough to handle, and a few are very large indeed.

Wherever Red Clay is dredged from the ocean deeps this meteoric matter is always present. It is exceedingly interesting, because it gives us a chance to analyse actual matter that has travelled from regions beyond the earth—the only chance we have. The submarine variety from the Red Clay is not the most suitable for analysis, however, because it has been acted upon by sea-water; but it gives us a clue to the amount of matter brought to earth by the meteoric rain. One might suppose that 400,000,000 meteorites a day would add something appreciable to the earth. They do not. It has been estimated that they only add to the earth

a layer of one-thousandth of an inch in thickness in a million years. How can that be said? Well, the organic remains that cover vast areas of the ocean-floor in shallower waters are almost all dissolved before they can reach 3000 fathoms. At that depth there is left only insoluble mineral matter—volcanic dust, mineral dust, cosmic dust that has come out of the atmosphere. Yet there are some organic remains, and very strange ones. The Red Clay yields quantities of ear-bones of whales and the teeth of sharks, which from their peculiar hardness are able to resist the solvent action of the water. Some of the teeth and ear-bones belong to species that have been long extinct. Yet so slowly is the material of the Red Clay laid down, that these extinct bones can be dredged from the deeps along with the pumice and the cosmic spherules by apparatus that can no more than skim the surface of the ground. The great authority, the late Sir John Murray, has stated that the rate of deposition of the Red Clay is so slow that probably no more than a foot in depth has become deposited since Tertiary times.

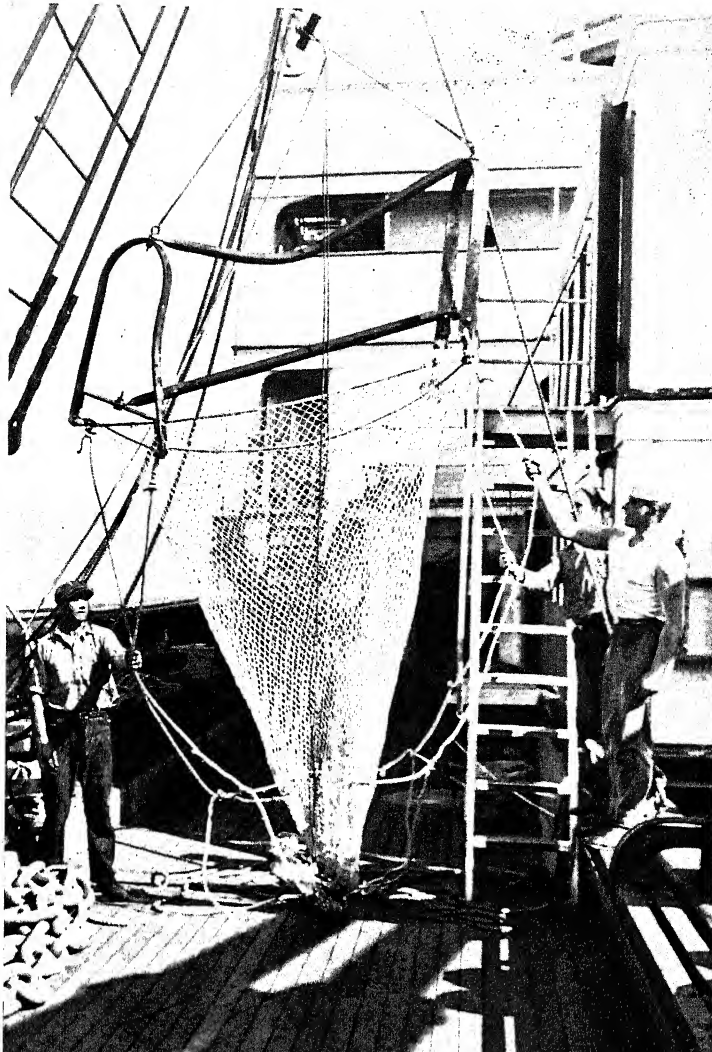
There is another constituent of the Red Clay that invests it with a deeper interest for science than any of the other deep-sea deposits. It is richer in radium. How does it happen that radium is present in greatest quantity in those very great depths, far from land, where the rate of deposition is slowest? Is it connected in some way with the presence of the cosmic dust? These are questions as yet unanswered. Nobody knows, or dares hazard a theory, even, though the significance of the connexion is obvious. It may well be that every new sample of Red Clay dredged for examination is a further step towards a solution of this great mystery.

CHAPTER VI

Oceanography

We had better go home by boat. For here, waiting for us off the long, rolling, submarine plateau of the Banks, is a well-equipped research ship. By making our return in her, we shall be privileged to see something of the methods by which the fascinating science of oceanography is being constantly built up and its discoveries welded together. I would like you to feel, before we have done with our voyage, what a very romantic science it is. Or, to put it another way, how interesting is the spectacle of *all* the sciences earnestly striving to unlock the mysteries of the Seven Seas—geologists, physiologists, chemists, biologists, zoologists, botanists, all at work uncovering, sorting, arranging the truths that await their search in the profoundest deeps.

Oceanography is a very modern science, as I pointed out in an earlier chapter. It is rather difficult to find a " father " for it, for, of course, there were many pioneers. Captain Cook was one, Sir James Ross another; in 1831 Charles Darwin made his famous voyage in the *Beagle.* By the middle of the nineteenth century there was a general feeling in scientific circles that the time had come for a better understanding of marine life, marine phenomena generally. In 1868 a little group of naturalists went a-dredging in the deep sea in H.M.S. *Lightning*. That was truly an historic event, for it resulted in the discovery that there was life in the sea at far profounder depths than had been thought possible, and one upshot of it was the fitting out of the *Challenger*



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DEEP-SEA TRAWLING

A ten-foot net dredge used for a three-mile drop to the Atlantic bottom hauled aboard the *Arcturus* of the New York Zoological Society's expedition to the Sargasso Sea. The expedition was led by Dr. William Beebe.

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expedition, a more ambitious enterprise in every way. The voyage of the *Challenger* really laid the foundation-stone of modern systematic oceanography.

The leader of the *Lightning* cruise was Charles Wyville Thomson, a very distinguished Scottish zoologist. In view of the experience he had already gained in the *Lightning*, and a year or two later in the *Porcupine*, no less than because of his natural talents, Wyville Thomson was given charge of the scientific department of the *Challenger* expedition. One member of his staff was John Murray, then a young man of thirty-one, whose name and work were destined to become far better known than those of the young man's leader. Murray was a Scottish-Canadian who had developed, while a child, a passion for natural history. After his education was finished he was able to turn his bent to good account during a trip to the Arctic in a Scottish whaler. The results of that voyage made him a valuable addition to the trained band of observers on board the *Challenger*.

The famous little ship sailed from Sheerness on 7th December, 1872. The *Challenger* was a corvette, a barque-rigged sailing ship with auxiliary steam, a very popular type of " light cruiser " in the Navy at that time. She was of 2300 tons, and the British Government, determined for once to be generous in the interests of science, fitted her out for her work in a very thorough fashion. There were a laboratory, a natural history work-room, an aquarium, and all the appliances and apparatus that forethought could provide. Thus equipped, the *Challenger*, commanded by Captain Nares, set forth with an assortment of scientific investigators on whom, one fancies, the naval ratings must have looked with some amusement.

Sixty-nine thousand nautical miles were logged before the *Challenger* dropped anchor in an English harbour again, three and a half years afterwards. Up and down and round

the world she went, sounding the depths, mapping the basins, probing the physical nature of the waters, and examining the life in the Atlantic, Pacific, and Southern Oceans. Those three and a half years of ceaseless experiment and investigation really laid the foundations of ocean science. Professor Wyville Thomson was knighted, and the same honour was subsequently conferred on his young assistant, John Murray. The results of the expedition were presented to an eager scientific world, at first under the joint editorship of Thomson and Murray, and on Thomson's death in 1882 the preparation and publication of the unfinished volumes was carried on by Murray alone, very largely at his own expense. The *Reports* were not complete until 1895, in which year the fiftieth volume was issued.

Sir John Murray's activities in the science of the sea continued right up to the time of his death in 1914. In 1910, he helped to organize the cruise of the Norwegian research steamer *Michael Sars*, another famous expedition which brought valuable results. But Sir John Murray was more than the "father" of oceanography. He was a man of very wide sympathies and interests, and a generous humanitarian outlook. He was much more than a great scientist, indeed, for his strong personality, his keen sense of relative values, his ability to direct and control, stamped this great Scotsman as a natural leader of men.

Many oceanographical expeditions have been sent out since the days of the *Challenger*, and nearly all maritime states have helped in the work of investigation. There have been established elaborate and costly research stations on land, some of them housed in very imposing buildings. A great many aspects of the life-histories and the complex functions of marine plants and animals are best studied in ampler and more stable conditions than it is possible to provide on shipboard, and the coastal land laboratories are

doing highly important work in gradually unravelling many puzzles of sea life that are only dimly understood, as yet, or not understood at all. The most important marine station in Great Britain is the laboratory of the Marine Biological Association at Plymouth, an institution now world-famous. The Ministry of Fisheries has a well-equipped station at Lowestoft, the Scottish Fishery Board another at Aberdeen, while the Universities of Durham and Liverpool also maintain appropriate stations. Norway, Sweden, Denmark, Germany, France, and Italy, the United States, Canada, and Japan have all equipped marine laboratories and stations for investigation, and permanent research ships belonging to those countries are continually enriching science. At the beginning of the twentieth century there was instituted the International Council for the Exploration of the Sea. Its head-quarters are at Copenhagen, and it is the chief authority for standardizing and co-ordinating the work of the ships and shore stations.

All this research activity goes to show that progressive nations are now very much alive to the practical importance of ocean science. "Oh!" somebody raised his eyebrows, "*Practical* importance?" Most assuredly. You don't suppose states and statesmen are allowed to waste money on mere inquisitiveness, surely! You and I may spend our lives and fortunes on academic speculations, but public bodies look for results that will ultimately yield a balance that can be recognized in terms of material prosperity. Of course, whatever aids science aids mankind in the long run —even all sorts of things that short-sighted people often regard as futile. Things such as aeroplane "stunting", speed trials, getting to the top of the Himalayas and to the bottom of Loch Long, flying to the Poles—in all such escapades or endeavours there is a net gain to humanity if the text of the lesson has been properly studied. But this science

of oceanography touches us all immediately. You may not like fish in your diet, but the things you do like are mostly the easier to get because ocean science is seeking to produce more fish. Your every material need is more easily satisfied because ocean science makes the seas safer for shipping. Your daily bread is largely dependent on the weather that ocean science can foresee more and more accurately for you. Your body in sickness and health, in everything you do, is more in your control on account of the discoveries of ocean science. There is no property of matter, no function of living cells, no organism simple or complex, that ocean science does not help every day to render plainer.

And so, knowing a little of the history and significance of oceanography, let us board the research ship. She is not, I fear, a beautiful vessel; her lines are not graceful, but rather the reverse. She is bluff, squat, dumpy, and a trifle under-sized, one thinks, to be knocking about the Atlantic in all weathers. She certainly doesn't promise speed, and we must be content with a modest 10 or 12 knots. But she is a very "stiff" little boat; and once on board, we begin to be impressed by an unexpected yacht-like appearance. Though her small deck is rather encumbered by derricks and winches, and the particular apparatus of her mission, there is no lack of paint and polished brass work. And evidently the work aboard her does not cease with daylight, for we observe that there are many lights about her decks, clusters of electric lamps with wide white shades. Entering the deck-house amidships we find, not the expected saloon, but the laboratory, with a long metal-topped table fitted with "fiddles", at one end of which is a rather formidable collection of chemical apparatus. But the most arresting things about the laboratory are the rows and rows and ranks and tiers of empty bottles and jars. They look uncommonly like milk bottles, d jars taken from a sweet-shop.

A research ship may be equipped and commissioned for a particular branch of oceanographical work, as in the case of fishery research. But this boat on which we now imagine ourselves to be berthed covers the whole field of ocean investigation. The list of the physical observations she is called upon to make is a truly formidable one. She must sound the bottom, as frequently as may be, and whenever the sounding-gear goes over, her staff require to know not the depth merely, but the nature of the bottom, and the temperature at the surface and at the bottom and at intermediate depths. They must also examine samples of water from different depths in order to ascertain the salinity, specific gravity, dissolved gases, minute constituents, and other matters. They must measure the force and direction of the currents at many different depths, and the transparency and power of penetration of light—all these things apart from the study of the benthos, plankton, and nekton.

It probably never occurs to anyone that taking soundings is anything but a simple business. All that is necessary is to throw a weighted line overboard; as soon as the speed to which it pays out is checked, you know you have touched the bottom. Well, try it, the next time you are in a small boat, and if it is a first attempt you will be wise not to take a facetious friend. No, sounding with the hand lead is a matter of skill and practice; it has to be learned, like everything else. The hand lead is a 14-lb. weight on a line of 20 fathoms, marked at intervals of two or three fathoms with bits of coloured cloth and leather of distinguishing colours. The leadsman takes his station on a small projecting platform called the " chains ", swings the lead several times and lets go in such a way that the line is carried well forward. He has to haul in the slack and read the soundings to the nearest mark as the line becomes vertical. " By the mark ten " he calls out, if the depth of water happens to correspond with the ten-

fathom mark, or " by the deep nine " if it happens to be a fathom less than the ten-fathom mark, and so on. But twenty fathoms is shallow water, and although all ships carry a deep-sea lead, a hand-thrown line that can measure to a hundred fathoms, all large vessels carry as well sounding-machines. And when it came to sounding, not in hundreds of fathoms but in thousands, the problem became very difficult indeed. The hempen rope, marked at intervals of 100 fathoms, was wound on a great drum, and a sinker weighing two or three hundredweight took the place of the lead. The fathom marks were carefully noted as they passed out, but a difficulty in telling when the sinker had touched bottom naturally arose because the great weight of thousands of fathoms of rope continued to run it off the drum, and it was next to impossible to " feel " the difference in tension. On the *Challenger*, soundings made with a hempen line and a three-hundred-weight sinker were believed to be accurate, even in a depth of 4000 fathoms, to within 25 fathoms. The sinker was fitted with a plunger which detached the weight as soon as it touched bottom, and the suspension being thus relaxed the alteration in the speed of the line was more easily noted.

Admiral Mathew Maury, the enthusiastic oceanographer I spoke about in an earlier chapter, adopted an ingenious method of sounding. He used a big reel of strong twine, of known length, and tied a cannon-ball to one end of it. The cannon-ball ran the light twine out very rapidly, and as soon as the difference in the rate of paying out showed that it had reached bottom, Maury cut the twine. Then he measured what was left on the reel. The difference between the original length and the length remaining showed the depth of water. Simple, but not very accurate, and extravagant of string. And I have a feeling that Maury, being only a lieutenant in those days, may have been hauled over the coals for wasting cannon-balls.

The most brilliant of the scientific luminaries of last century, its virtual leader for forty years in physics, mathematics, electricity, was also one of the most active in his efforts for sea science. I speak of Lord Kelvin, of course—of him whom one never knows whether to respect the more his genius and attainments, or to love the more his modesty and gentleness. How I should delight to enlarge on that colossus of Glasgow University—that great, romantic, appealing figure, the Newton of his age! I could tell you how he matriculated at the age of ten, how he rowed at Cambridge; how he tortured his friends by his cornet-playing; how he could never carry out an experiment without spoiling it; and how some of the richest gifts of his rich invention took form in a coal-shed! But having said that much to whet your appetites, to make you want to read about him elsewhere[1] I can only refer here to Lord Kelvin's introduction of piano wire for deep-sea sounding. His chief concern at that time (1874) was the successful laying of the Atlantic Telegraph Cable, and he soon found the bulky and cumbersome hemp rope, three-quarters of an inch in circumference, entirely unsatisfactory. He wanted something thinner, more easily managed, quicker at running out and hauling in, offering less resistance to the water. He found it in piano wire. Strong, thin, flexible—its flexibility depending on the number of strands of which it is composed—such wire has since become almost exclusively used for deep-sea sounding. Piano wire, in fact, is almost as much an essential in the outfit of the oceanographer as it is in that of the piano-manufacturer.

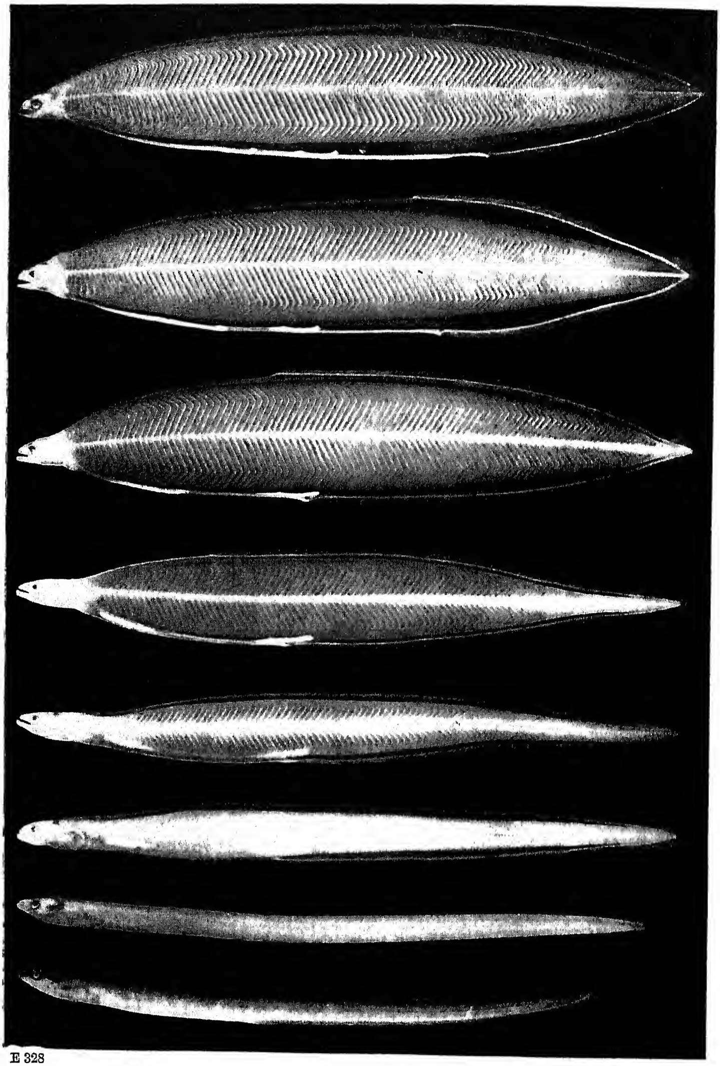
[1] *Lord Kelvin's Early Home*, by his sister, is a delightful study of the boyhood and youth of the great man and his distinguished brother, James Thomson.

CHAPTER VII

Searching the Deeps

Our research ship is heaving gently to the Atlantic swell, hove-to for sounding. Take a good look at the several steam winches about our decks. The big one amidships is for working the very heavy trawl, the smaller ones for lowering and hauling up the many different kinds of instruments that must be sent down thousands of fathoms deep. Wound up on the drums of these winches are miles and miles of stranded steel rope of different thicknesses and strengths. That on the trawling winch is a rope over an inch thick, with a breaking strain of eight tons or more. It is a truly wonderful product of manufacturing perfection. Six separate strands are twisted around a central heart of hemp, and each strand is a rope in itself, being built up of twenty-four separate wires. But trawling and sounding are very different things, and the sounding wire is much lighter and thinner.

If anyone is under the delusion that deep-sea sounding is a dull kind of job, a day or two aboard the research ship in mid-ocean would be sufficient to dispel it. If it failed to do so, only an extraordinarily dull sort of mind or the don't-care-if-I-die stage of sea-sickness could explain the want of interest. If his fancy remained cold under the stimulus of two miles, three miles, four miles of wire dangling in the unknown waters on which he floated, his is indeed a stubborn fancy. Down, down, down, mile upon mile through a world wonderful beyond belief of him who never tried to



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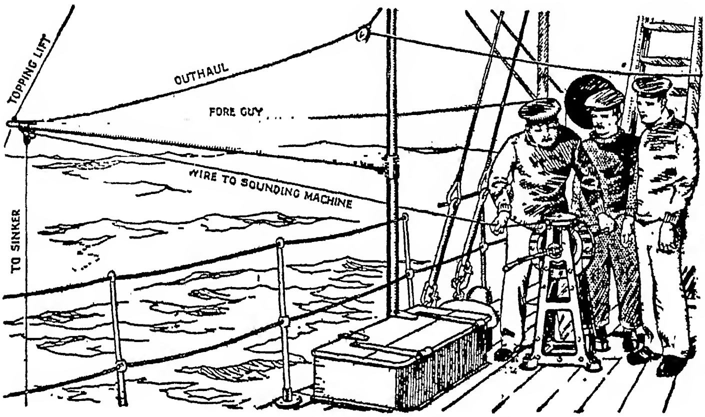
METAMORPHOSIS OF EEL LARVÆ

The top specimen is a full-grown larva before metamorphosis. The two lowest ones are Elvers. Actual length of top specimen is 3 inches.

Reproduced by courtesy of Dr. Johs. Schmidt

Facing page 77.

search in it; a world of beauty, of thrilling mystery, a world of life in forms so strange and fantastic that we gasp in wonderstruck amazement. Yes, it's a weird world, the deep sea. Who can be surprised that those who once venture upon its secrets are held in thrall for life? How else should men give brains, fortunes, work-time, and play-time in service of the enslaving science? And ponder this, when next you walk by the seashore. *You* came out of the sea, in that age-long



Taking a Sounding with a " Kelvite " Sounding Machine

childhood you have forgotten. Your body is mostly sea-water, your lungs inhale it at each unconscious respiration. Each of us carries many traces of the watery five-sevenths of the living earth. Yet we can never return to our first source, never see, each for himself, according to his vision, its beauties and its treasures. Dead—in five minutes. Such would be the terse epitome of a going back.

Down, down, down, mile upon mile. Only piano wire glinting in the sunshine, piano wire moving swiftly over a grooved roller. But it is a tense business for the group of watching men, tenser still for the operators, for many things

may happen before the bottom is reached. This is the Lucas sounding machine, beautiful in its sensitive simplicity, robbing deep sounding of most of its difficulties, but calling for skilled manipulation. The machine is fitted with a very sensitive form of brake, and as the wire runs out off the drum its increasing weight is compensated by adjustment of an ever-tightening band. There! the sinker has touched bottom, the brake acts and the wire ceases to run out. You can read the depth from the meter! But this is the most critical moment of all, for although the 50-lb. sinker became detached the instant it hit the bottom, leaving only a tube or a "snapper" to bring up a sample, the great weight of the wire is very near the limit of its breaking strain. There are anxious moments as the engine starts to wind in . . . if the wire kinks it will break. This freshening breeze is a nuisance. The short pitch of the ship puts a terrible tug on the three miles of slender steel threads, straining, straining in the dark heart of the blue. Did you ever see the like of this blue—a liquid ecstasy of colour, the lobelia of the garden-bed come to life? And there, astern in the cloud shadow, the world flows in moving bands of lead and silver and the hues of moonlit meadows.

There is a beautiful telepathy in the handling of the ship, an alertness of hand and brain that unifies the separate controls. The operators at the sounding machine, the helmsman, the command in the engine-room—they think and act as one. It is not easy to hold the ship glued to a speck on the bottom, with the breeze and the drifting water begging her to play with them, but that slender thread of steel must be kept vertical—dead up and down. But only the winding-engine fusses. The wire coils smoothly on the big storage drum and the danger of a breakage passes. We did not want to lose the wire, though in this case the loss would have been more aggravating than serious. Presently,

when we shall send down a load of valuable instruments, there will be more reason for anxiety. Did you look at your watch? That was a quick sounding; not above an hour and ten minutes from the time the sinker went overboard. It used to take two hours and more in the day of the old *Challenger*.

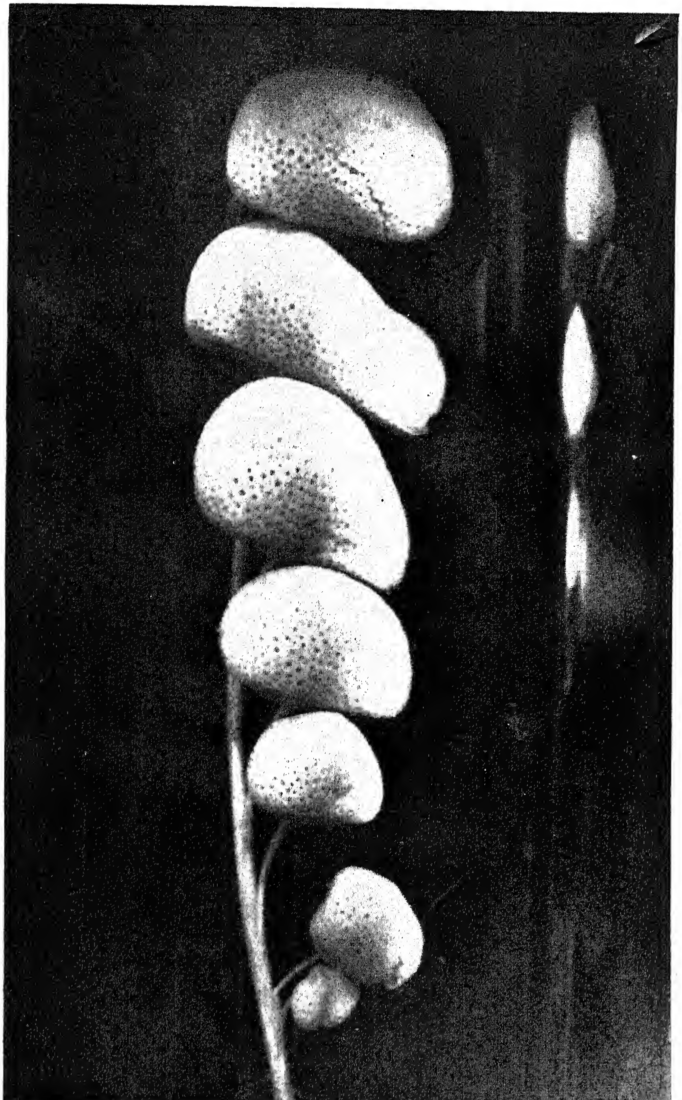
Well, I can hear some readers exclaiming, " Good Heavens! How archaic!" Yes, it is true that our method of sounding is going out of date; or sounding by any machine, for that matter. In a few years' time, probably, hand lead and deep-sea lead, as well as mechanical means of sounding, will be obsolete—just so many interesting stages in the unending climb towards perfection. Nearly all ships are being fitted with echo-sounding apparatus called hydrophones—warships, liners, cargo-boats, research ships, survey ships, even trawlers. Echo-sounding has a fascinating simplicity; anybody can work the device and read the depth of water under him as easily as he can tell the time. The underlying principle was a gift of science to the cause of safety at sea, and a thing that started as a scientific toy now lessens enormously the risks of shipping, removing at least a quarter of the dangers of navigating difficult waters in foggy weather.

The echo-sounding device is based on the knowledge that sound travels in water at a known speed (4900 feet a second), and that it is reflected from the sea-bed just as sound in air is reflected from a wall or hill. There are several forms of apparatus but the differences are in application and details. In the British system, originally introduced in the Navy, soon after the war, and now common in merchant ships, a small spring hammer generates the sound waves. In the American and German apparatus that function is performed electro-mechanically. In all of them there are three parts. On one side of the ship is the transmitter; the hammer in the British system beats on a steel diaphragm, at regular intervals, a

note with a frequency of 1250 vibrations a second. On the opposite side of the ship is the receiver or " hydrophone ", a very sensitive microphone which picks up the echo coming back from the bottom. On the ship's bridge the two instruments are connected in the recorder, the apparatus which measures the time interval between the sound impulse and the echo. The recorder does not even ask one to use his wits, but converts the time interval into terms of fathoms which can be read off a dial. *Our* sounding in 3000 fathoms with the machine took eighty minutes, just now; the echo-sounder does it in ten seconds, more or less!

There is another very wonderful echo-sounding device, the invention of Professor Langevin, of Paris. The sound waves transmitted in this case are so extremely rapid that they are far beyond the limit of human audibility. The oscillations come from a quartz plate, electrically vibrated. The important feature is that they can be directed as a beam —concentrated like a beam of a searchlight, instead of spreading in all directions, like ordinary waves. The advantage of the beam lies in its power to detect small alterations in the level of the bottom, and projections such as rocks and wrecks in shallow water.

On board our research ship sounding is part of the routine. That is why I have taken you rather fully into its ways and means. After all, most of the preliminary investigation has to be done with a line run vertically to the ocean-floor before observers have any data to work upon. One of the most fascinating things about oceanographical work is that it is, in large part, literally a groping in the dark. Nearly all the observations have to be made far out of sight and out of reach of the observers. It is really a very pretty notion, that of science reaching out into the unknown world, confident even when blindfolded. The oceanographer's instruments must feel and see and sense the things he can but



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A DEEP-SEA SPONGE

Its name is *Esperiopsis Challengeri*, and it was found near the Celebes. In the stillness of the abysses it has evolved an unusual symmetry of growth.

From a photograph by W. S. Berridge, F.Z.S.

Facing page 80.

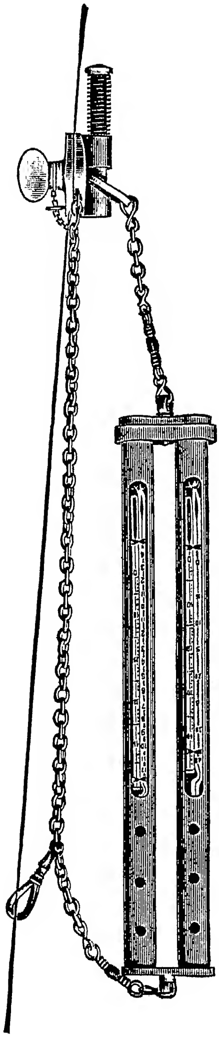
thus indirectly approach, and yet he must be satisfied that the impressions they record are correct ones. Science never leaves anything to chance, but in this underwater world its inventions of discovery need check and counter-check beyond the common.

Here are thermometers and water-bottles going down the line. You might not suppose it could matter much to anyone what was the temperature at this depth or that, but as a matter of fact the knowledge is of supreme importance. Temperature bears directly on behaviour of currents, and it also affects the life-histories of marine animals and plants in many different ways. Their larval growth, their feeding, their sexual development, their multiplication seem to be intimately connected with the temperature of the water. As I have suggested, a vast amount of inventive thought has been expended on the perfection of oceanographical instruments, and the problem of suitable deep-sea thermometers has been a very difficult one.

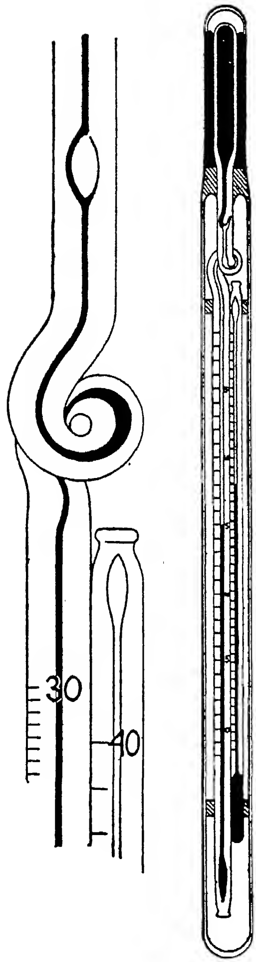
In the first place, the instruments must be certain to function at any given depth, and the information recorded at that depth must remain unaltered until they are again in the hands of the observer. For instance, a thermometer sent down to say, 2000 fathoms, passes through strata of varying temperature; as a rule, the deeper the water the colder it is, until at a depth of between two and two and a half miles it is only a degree or two above freezing and never varies beyond 2° F. throughout the whole area of the ocean. The ooze brought up in our sounding a while back was so cold that it will be some time before it can be handled! But it sometimes happens that the thermometers will pass through layers of uneven temperature—cooler, warmer, cooler, warmer, and so on. Clearly, though the journey down to the predetermined level does not matter, they must remain impervious to changes on the journey up. The

hauling in from a great depth takes time, as we saw when we watched the sounding machine. How are certainty of operation and the necessary inviolability secured? Insulation and check are the two safeguards. Water samples are always taken at the same time as temperatures, and the insulating water-bottle contains a thermometer. It is a very ingenious piece of apparatus, and consists essentially of two concentric cylinders carried in a strong metal frame and having, at top and bottom, two metal discs for closing the ends of the cylinders.

When the insulating bottle is being lowered, the water flows through freely, but when it has reached the required depth, a weight, called a "messenger" is sent down the line to close it, which it does by striking a spring. Such messengers are employed for operating all sorts of under-water gear. When the insulating bottle is hauled up it contains, of course, a sample of the water from the depth at which the messenger closed it, and the enclosed thermometer shows the temperature at that depth. But, can we be sure that the temperature has undergone no change? Is there any reason to suppose that something has happened on the way up to make it mislead us? Well, you know that compression raises the temperature of water, therefore our sample will lose heat as the deep-sea pressure gives place to that of the atmosphere. Clearly it will be *colder* when it reaches the deck of the ship than when it entered the water-bottle at 2000 fathoms deep—and that is where the check is necessary. For this purpose there is sent down at the same time as the insulating water-bottle a special thermometer carried on what is known as a reversing-frame. The thread of mercury in the thermometer has an S-shaped bend in it, and when it is turned upside down by the sudden impact of the messenger acting on a spring in the reversing-frame, the thread of mercurv is broken. The thermometer is unable



Reversing Frame



Detail of " Constriction "
and " S Bend "

Deep Sea Thermometer

By permission of Messrs. Negretti & Zambra.

to function with an incomplete column of mercury, and so it comes to the surface again with a record of temperature at the depth at which the messenger put it out of action. By this means it has become possible to compile tables from which the loss of temperature due to decompression of water brought up from the deep can be easily calculated.

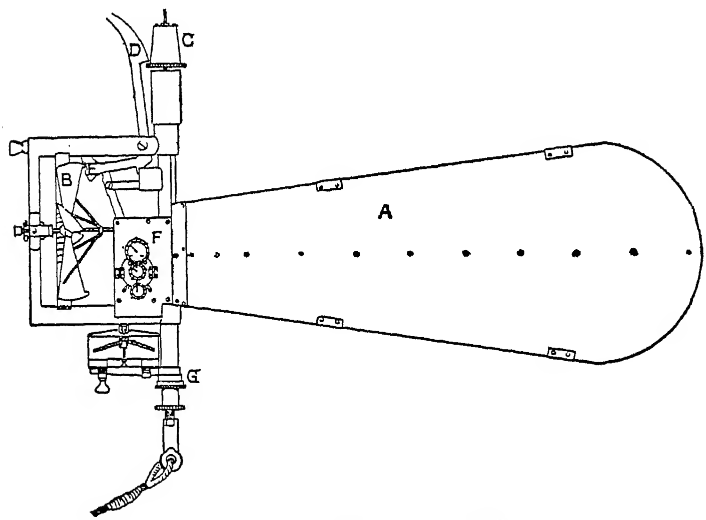
As you may imagine, it was a very difficult matter to contrive efficient protection for thermometers and other instruments against the enormous weight of the water at great depths. Remember that the weight of the atmosphere bears at sea-level with a pressure of 15 lb. to the square inch, and that 33 feet of sea-water weigh as much as the atmosphere. At that depth, therefore, the weight of the water equals that of two atmospheres, at 66 feet three atmospheres, at 99 feet four atmospheres, or 60 lb. to the square inch, and so on. At a depth of a thousand fathoms the pressure is 12 tons to the square inch, at 2000 fathoms it is twice that pressure, at 3000 fathoms three times—36 tons. Sir John Murray relates how the thermometers used to be smashed in deep water—"imploded", the reverse of exploded—and how experiments were made to determine the effect of pressure on various substances. Sealed glass tubes were wrapped in a cloth, enclosed in a copper cylinder perforated at the ends to admit water, and sent down to 2800 fathoms. When the cylinder came up again it looked as if it had been violently struck with a hammer. On undoing the cloth the glass tubes were found to have been crushed to a fine powder that looked like snow. Blocks of wood that have been sent down to great depths on being brought up again sink like stones, owing to the implosion of the tiny cells. It is only by the use of an extraordinarily tough sort of glass that oceanographical thermometers can be protected against the pressure.

The pint or so of water contained in the water-bottle that

came up is very precious and goes at once to the laboratory. Samples must be analysed in all sorts of ways in order to discover such things as the amounts and natures of the salts contained in them, their viscosity or "thickness", the gases dissolved in them, and other properties that are too technical for us. But they are all highly important and not just academic. One very important matter that science is trying to resolve is the density of life in the sea at different depths. It is not enough to know what sorts of animals and plants there are; it is necessary to know how many of each sort. Well, the water-bottle has brought up life in forms invisible except to the microscope, and the forms must not only be named and classified but actually counted as well. How many tiny organisms of this sort or that, are there in this pint of water? The problem is not as difficult as it sounds. The water is "centrifuged" and by this means the particles in suspension can be concentrated in a tiny space. The water is turned into a test-tube having one end drawn out to a thin blunt point, and this tube is revolved in a machine which spins it at the rate of 700 or 800 revolutions a minute. The machine is generally arranged so that it can centrifuge several tubes at a time. After a few minutes' spinning all the organisms are collected in the thin tapering space at the bottom of the tube. The water is th poured away, all except the tiny drop which remains at the bottom of the tube. This drop is transferred to a slide with ruled divisions and the organisms present can be counted under the microscope.

The miles of piano wire run out over the grooved wheels that count the fathoms and all sorts of delicate devices bring forth their messages of discovery. Cameras go down to measure the character and intensity of the light, and, for the same purpose, the more acutely sensitive contrivances known as photo-electric cells. Now the ship is hove-to for

current investigations. When the thermometers and water-bottles were under discussion on page 81 it was pointed out that temperature and salinity had an important influence on the flow of currents; and these, again, directly affect the lives and functions of their inhabitants. Currents must be studied, therefore, and once more the study calls for special



Ekman Current Meter (after Gardiner)

A, Vane. B, Propeller. C, First Messenger. D, Arm to unlock and lock. E, End of D carrying slot which engages with B. F, Box containing revolution-counter and shot store; below this is the compass-box.

methods. What do you think of this device, the Ekman current meter, that will both measure the velocity of a submarine current and reveal its direction as well? Look at it on the wire before it goes down. On one side of the hollow central spindle through which the wire passes is a big rudder, or vane; on the other side is a rectangular frame carrying a geared propeller. One end of the propeller-spindle enters a box, on the front of which are dials with pointers, and this

box is also a magazine containing small lead shot. Beneath this box there is a compass with a heavy magnetic needle, with its two arms inclined downwards, and one of the arms, the north pointer, is deeply grooved.

Down goes the instrument; and when it has reached the required depth a messenger is sent down the line to release the propeller. And then, this is what happens. The meter is " steered " against the current by the big vane; the water moving past it turns the propeller. At a given number of revolutions, click! a shot falls out of the magazine, rolls down the grooved needle and falls on to the compass card beneath, which is divided into compartments at intervals of 10°. The shots comes down faster or slower as the strength of the current turns the propeller. After a time a second messenger goes down to stop the mechanism, and when the meter is brought up, the direction and velocity of the current can be read off from the position of the shots in the compass card and the number of revolutions shown on the dial.

There are so many fascinating operations to command our interest and admiration on this research ship that, as she steams her easy way towards Plymouth, we may wish that some miscalculation might take her half around the world, instead of homeward bound. Sometimes she lies hove-to, and as she rolls to the eternal rhythm of the wide Atlantic there is a special eagerness aboard as some novel experiment is made, some particular result anxiously awaited. We have not seen a fiftieth part of her work. We might have watched the great grab that gouges out chunks of the sea-floor, or the other devices for bringing up specimens of the ice-cold bottom. And the great nets and trawls and dredges that take up so much of the ship's storage-space—they have been going out and coming in, day and night, while we have been concerned with other things. The big trawls, indeed, provide most of the thrills, and sometimes more excitement

than anyone cares about. The cable may take charge of the cable-drum and race out uncontrolled, and when that happens limbs and even lives are in jeopardy. With four miles or so of cable paid out the strain is equal to four or five tons, and if anything happens to alter the tension the men in charge must be instantly alert to counteract it. So the instrument that shows the pull on the cable is anxiously watched, and winches, drums, derricks—all the gear—must needs be in perfect order. You can't send down a deep-sea trawl and then take a nap! In high latitudes the work is more hazardous still, for if floating ice catches or impedes the cable something is bound to fly.

The naturalists in the laboratory are dissecting, examining, classifying. The microscope pries into the stomachs of minute animals and there studies life still more minute. The rows of glass bottles and jars are filling up. Charts, tables, graphs, measured drawings, and photographs are accumulating to form records of the voyage. Of this work we have seen nothing. The wonders of the life in the sea, the great gasping animals that were caught in the big nets, and the tiny creatures that were too small to pass the imperceptible meshes of the finest silk tow-net—well, that investigation is so important and so complex that I dare not attempt a summary now. We may find another opportunity, later on. We must leave now the little band of scientists—laughing, joking, working to all the fickle moods of the northern seas. How closely they seem linked to those older explorers whose ghosts ride triumphant over the watery plains! Ghosts of the crews of Cabot, ghosts from the Grand Banks, ghosts from the polar wastes—these new men are your men, richer in wisdom from the ripening years, yet one with you in spirit and tradition. The same men—claiming a loftier humanity and university degrees.

CHAPTER VIII

How the Winds Rule the Ocean

Winds and waves generally go together, as everyone knows who has ever seen the sea. Indeed, the currents in the air and the currents in the oceans are far more intimately connected than appears at the first glance. Everyone knows something about air-movements in these days, but to get at the influences that set the seas in motion we must go back for a moment to consideration of the geospheres.

Take, then, the atmosphere from the geospheres and have a good look at it. That body of oxygen, nitrogen, and water-vapour that gives us our being, is an astonishingly slender thing. If the earth is an orange (slightly sucked, remember), then the atmosphere is equivalent in volume to the thin tissue paper in which oranges are generally wrapped. The pressure of 15 lb. to the square inch that is about the average at sea-level is the actual weight of the mass of air vertically resting on that level. Go up 18,000 feet, not quite 3½ miles, and half the weight of the air is underneath you; go up 36,000 feet (which of course you can't) and only a quarter of the weight bears on you. If you *could* ascend to 60,000 feet, then nine-tenths of the weight and mass of the atmosphere would be beneath your feet.

Now for the rhythms set in motion by the sun in this very thin, mobile envelope of gas. There is a belt around the earth, the tropical zone, on which the sun's rays fall almost vertically, which is consequently heated to a very much

greater degree than the rest of the earth. It is important to remember that the heat rays coming directly from the sun pass *through* the gaseous particles of the air with very little effect upon them. The air itself becomes warmed by

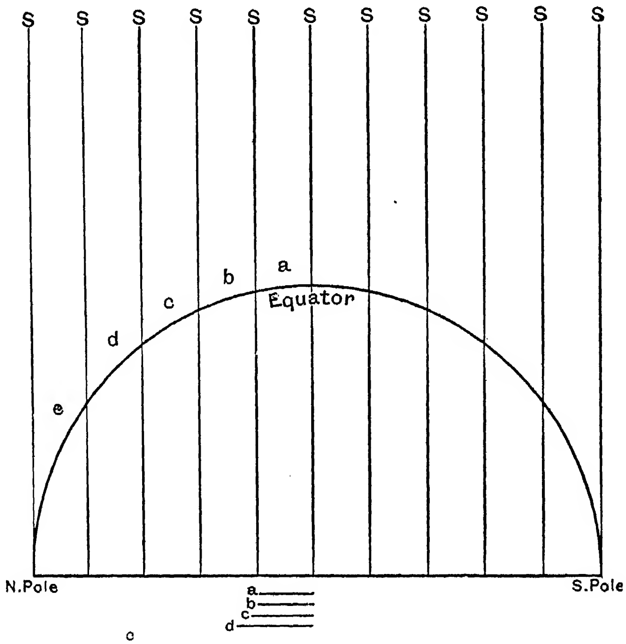


Diagram illustrating the unequal division of heat received from the sun. If the earth's surface were flat each equal width would receive an equal amount of heat; but as the earth's surface is curved the amount of heat received by the width *a* at the equator is spread over the width *e* near the poles.

reflection—by radiation from heated surfaces. It thus follows that the air in any part of the earth receives by reflection only so much heat as can reach a given surface. Because the earth is a sphere, only a little of the curved surface can receive the heat rays at right angles; most of the surface gets the heat more and more obliquely, until, as

the Poles are reached, the rays have had such a long slanting journey through the atmosphere that most of their heat has been reflected back before they can reach the earth.

The radiation of the heat received by the earth in the equatorial zone causes the air over that zone to expand; its density becomes less. Consequently it rises, and its place at the surface is taken by cold air from an upper strata of the atmosphere. There is thus an area where the air is lighter interposed between two areas where the air is heavier. An atmospheric wave is created, the crests of the wave occurring over the high-pressure cool areas and the trough over the low-pressure warm area. If the surface of the earth were smooth and its land surfaces composed of the same material everywhere, we should have no need of barometers to indicate the alteration in the pressure at different points. In such a case, the crests of the waves would move with a regularity that would soon enable us to measure them.

Such is the first atmospheric rhythm—and the first wind. The air is set in motion; rushing from the high-pressure areas to " fill the gap " caused by the ascending column where the weight is less. But it doesn't flow as a current of air having a straight course. The movement is nearly always spiral, inwardly from the high-pressure to the low-pressure areas.[1] We see that in the pulsations of air pressure consequent upon unequal temperature, arise the primary air currents. At this stage another force comes into play—the rotation of the earth. The speed of any spot on the equator is something over a thousand miles an hour—about three miles a second; and this speed of course decreases more and more towards the poles until it reaches a theoretical zero. But until it is disturbed, the atmosphere moves at the same speed as the solid ground beneath it; which is rather an

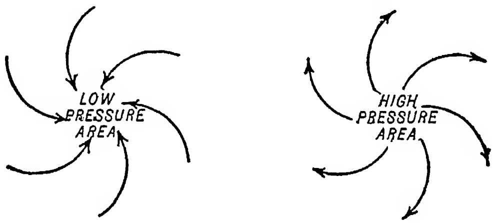
[1] Hence the winds from these areas are *cyclones*. The areas of high pressure, from which the winds blow outwards, are *anti-cyclones*.

important point to remember because it is sometimes stated that the air movements we call wind are *caused* by the velocity due to rotation. The earth's rotation undoubtedly does influence matter set in motion upon it, but it cannot cause motion. If it could, I fancy that the croquet-balls on a nice level ground near the equator might be off on a pretty little game of their own. " I do hope it will be calm!" is an unspoken prayer from the hearts of hundreds of bad sailors contemplating Channel crossings. They might elaborate it, " I do hope the rotational speed of the air will equal that of the water, so that there may be no wind!"

But the winds being once set in motion, the velocity of the earth takes them in hand. The effect is to make them deviate towards the right, or west, in the northern hemisphere and towards the left, or east, in the southern. There is thus a definite relationship between wind and the distribution of pressure, that holds true of every cyclone or anticyclone, great or small, wherever it may occur. This is the Law of the Winds, enunciated by the Dutch meteorologist, Buys Ballot: " Stand with your back to the wind, and the region of lowest pressure will be on your left-hand side, and slightly in front of you." In other words, the cyclonic area is on your left, and the anti-cyclonic to your right. If you live in the southern hemisphere you must reverse that.

If that were all—only the " first causes " I have indicated —climate would be a very simple matter and meteorology the world's least necessary science. There would be no weather and no use for broadcast weather forecasts. But complications arise to confuse and confound the poor meteorologist on every hand. The earth is made of many different things, all of varying power to absorb and retain d reflect the heat rays. Its surface is irregular; and day and night, summer and winter, cause recurring but inconstant

waves in the blanket of air resting on any particular part of it. A further complication is introduced by the fact that water-vapour is a good deal lighter than air, and that the capacity of air to hold it depends on its temperature. The solar heat is not even the only source of air-heat, for every variation in pressure—that is, of volume—is accompanied by an interchange of heat. Everybody knows that when air is compressed, part of the energy required to compress it is converted into heat, and that the converse is equally true—an expanding body gets colder. There are constant changes



Direction of movement of the air in a cyclone in the Northern Hemisphere.

Direction of movement of the air in an anticyclone in the Northern Hemisphere.

of volume between the up and down columns of the atmosphere. Whether the air moves vertically up and down (which it very seldom does) or along an inclined plane, its temperature will have been lowered or raised, according as it ascends or descends, by 1° F. for each 180 feet of change of level. One might, indeed, be pardoned for supposing that out of such confusing and conflicting forces rhythms could never come. Yet they do, unerringly.

Understanding of the winds and the forces impelling them is one of the tests of good seamanship. It was one of the things Admiral Maury was so very keen about. In the old sailing days this understanding went to the making or marring of master mariners. Even now, no ship can afford to ignore the rhythms of wind and weather. I doubt really,

whether any of us can afford to. Climate touches everything that lives, and climate is simply weather on the grand scale.

Think then, of the sun's rays pouring down vertically upon the earth's waist. The heated air ascends, the year round, creating a permanent belt of low pressure—a cyclonic area—towards which the winds blow in from the cooler belts north and south, where the pressure is higher—in other words, from anti-cyclones. Now, the centres of the spirals, whether the air moves *outwards* and downwards from a high-pressure area, or *inwards* and upwards from a low-pressure area, move less vigorously than the outer streams. You would therefore expect the centres of both cyclones and anti-cyclones to be relatively calm, and this is actually the case. Let us suppose that we are now in the Doldrums, the belt of equatorial calms. The position of this belt is not quite on the equator, but slightly to the north of it, between 5° and 10° N. latitude, with a tendency to swing with the sun to north in the northern summer and to south in the southern. There is hardly a less pleasant region in all the ocean.

> "Down dropt the breeze, the sails dropt down,
> 'Twas sad as sad could be;
> And we did speak, only to break
> The silence of the sea!"

There is no better picture of it than that. Ships and men alike become listless. Sails idly flap in the intervals between tricky variable breezes that bring no relief from the heat that blisters paint-work and makes steel decks and wire-rigging unbearable cruelties. To the steamer, there is comfort in the monotonous pulsing of the propellers bearing her out of the inferno towards the windy zones to north and south. Do you remember the old *Patna*, with her 800 pilgrims?

"She held on straight for the Red Sea under a serene sky, under a sky scorching and unclouded, enveloped in a fulgor of sunshine that killed all thought, oppressed the heart.

withered all impulses of strength and energy. And under the sinister splendour of that sky the sea, blue and profound, remained still, without a stir, without a ripple, without a wrinkle—viscous, stagnant, dead. The *Patna*, with a slight hiss, passed over that plain luminous and smooth, unrolled a black ribbon of smoke across the sky, left behind her on the water a white ribbon of foam that vanished at once, like the phantom of a track drawn upon a lifeless sea by the phantom of a steamer." [1]

The Doldrums are not always sunny. Indeed, the equatorial belt is frequently cloudy, with thunderstorms and torrents of rain, and an atmosphere close, steamy, fearfully oppressive. It is sometimes called the "cloud-ring". Refrigerating machinery and forced ventilation have robbed the Doldrums of much of their earlier terrors, but still they are bad to traverse. They used to be known as the *Wayside Grave* in the days of Australian emigrant traffic before steam. The overcrowded ships from Europe were baffled in them for two or three weeks—longer sometimes—and the debilitated passengers suffered terribly. Women and little children used to give up the struggle, and the sail-cloth shrouds were lowered overboard with dreadful frequency.

Into this central low-pressure belt the winds blow strongly from the anti-cyclonic areas north and south; splendid, invigorating, invaluable winds—the Trades. There is vast significance in the word, for trade is the Anglo-Saxon *troed*, to tread. To Shakespeare it means the beaten path, the track that comes by trading. And in like manner the Trade Winds are the winds that beat a path around the oceans. They blow steadily, rhythmically, the year round, not north and south, because the earth's rotation gives them an easterly "pull". The two opposing masses of air coming towards the equator from the high-pressure belts are therefore

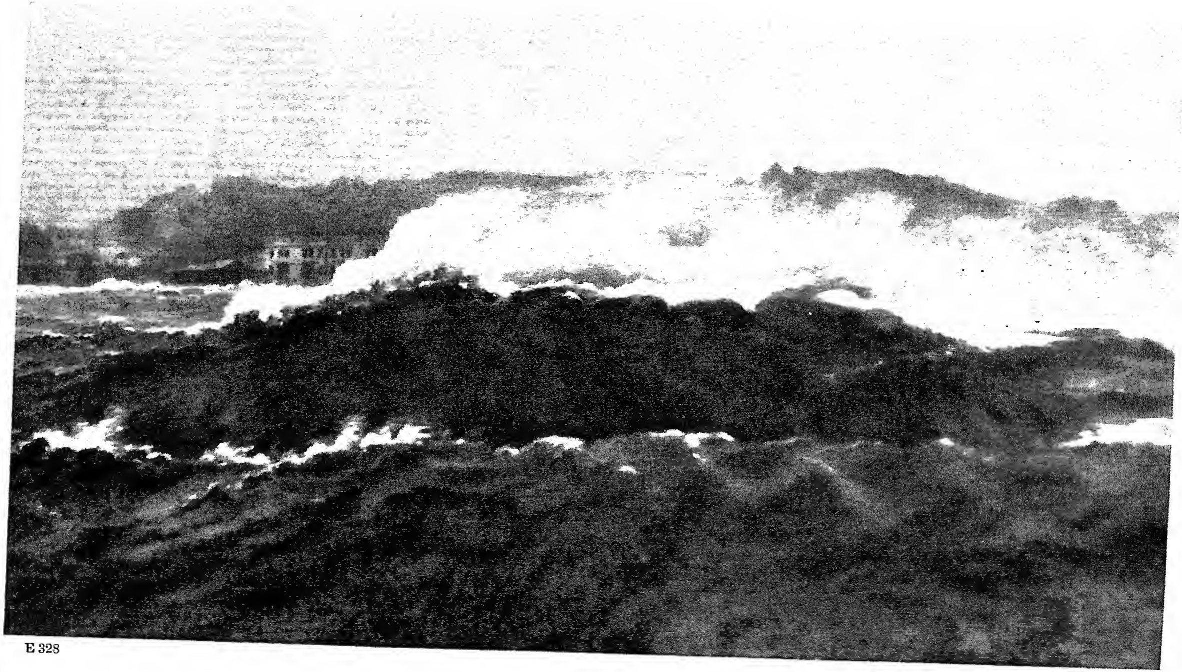
[1] Joseph Conrad: *Lord Jim*.

deflected, so that the Trade Winds are always blowing from a north-easterly direction in the northern hemisphere and south-east in the southern.[1] These permanent winds blow in the Atlantic and Pacific between the parallels of 27° N. and 27° S. and the northern and southern limits of the equatorial belt respectively with only very small seasonal variation. " Here the Mariner," says Maury, speaking of the north-east Trades, " finds the sky sometimes mottled with clouds, but for the most part clear. Here, too, he finds his barometer rising and falling under the ebb and flow of a regular atmospherical tide, which gives a (relatively) high and low barometer every day with such regularity that the hour within a few minutes may be told by it."

There is one great variation in the persistence of the north-east Trades that is highly important. It is only necessary to look at the map to get a feeling that the mighty winds of the earth, though conforming to a general symmetry, cannot be quite as regular as the cyclonic theory implies. It is obvious that since land and water have such different capacities for absorbing and retaining the heat that is the fundamental cause of the air movements, there must be many local variations of pressure. All land masses *must* create secondary cyclones and anti-cyclones to merge into the major ones and swirl and eddy about their skirts. Only in the great Southern Ocean indeed, are the brave west winds nearly always blowing. But to that digression I may return. The great variation in the rhythm of the north-east Trades is this: (keep the map out, because it helps)

The southern half of the continent of Asia becomes intensely hot in summer, with the result that there is formed over it a region of low pressure, towards which the winds

[1] At St. Helena, which lies in the centre of the south-east Trade-wind region, the south-east wind blows day after day with no more variation than a point or two in direction, and a few miles per hour in velocity.



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TYPHOON

Photographed in Hong-Kong Harbour during one of the most devastating tempests that ever swept the Chinese Seas

Facing page 97.

blow in from the Indian Ocean and the China Sea. The normal south-east Trade Wind of the Indian Ocean is consequently deflected or sucked towards the table-land of Central Asia, and becomes a south-west wind. This is the south-west monsoon. The moisture it has drawn from the ocean is of immense consequence to the peoples of India. The change of the monsoon occurs in October, and from then until April the Asiatic plateau is much colder than the surrounding oceans, with the result that during that period it becomes an anti-cyclonic (high-pressure) area. During this winter phase the winds are north-east, blowing out to join the north-east Trades, with which they become identified.[1]

A belt of calms about the equator, the Trades to north and south of it, and then, north and south of these again, more belts of calms. These calms are the central portions of the high-pressure areas from which the Trades blow—the spaces on the outer or polar sides of the Trades. The northern high-pressure calm area runs roughly along a belt at 30°–35° N., and the southern, the calm belt of Capricorn, is about 25° S. latitude. The Capricorn calm belt need not concern us, except in so far as it obeys the general rhythm; but the northern calm belt is called the Horse Latitudes. Queer, that, because being calm there, you would not expect "sea-horses". What winds there are, are light and fluky. The horses, alas! were real enough that gave the name to these latitudes. There used to be a big traffic in horses to the West Indies, many years ago. They were imported from Europe and from North America as well—profitable deck cargoes for ships outward bound. Cross this calm belt they must, poor creatures, by whichever route they came, this

[1] The term monsoon, "a season", is now applied to any periodic cyclonic system originating from the seasonal or daily differences in the temperature of land and water. Thus, North America, North Africa, Australia, and nearly all islands develop their own monsoons. We have ours in Britain—too many of them!

belt where ships lay becalmed and drifted idly for days, for weeks, while fresh water grew scarcer and scarcer; until, all too often, the casks were emptied, quite. Then tackle was rove and overboard the wretched horses had to go.

Beyond the calms under the centres of these anti-cyclonic belts, as we go north or south towards the poles, the conditions

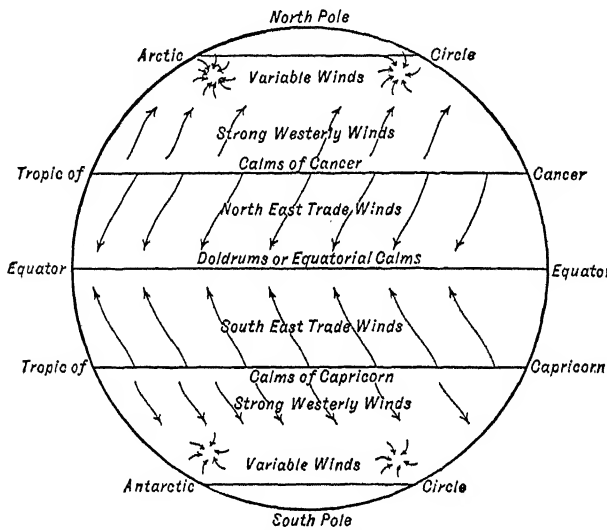


Diagram of the Wind Systems of the Earth

in the two hemispheres are not quite alike. To sail southwards is to sail away from land; to sail northwards is to approach the greatest land-area of the globe. Yet the atmospheric balance is the same in both hemispheres, the difference being that in the northern it is more susceptible to local vagaries. In both cases the pressure decreases as higher latitudes are reached, rising again to form anti-cyclonic areas above the Poles.[1] Now, the air movements are circular;

[1] The systematic meteorological observations were among the most important results of the Scottish National Antarctic Expedition of 1902-4. One remarkable achievement was that the *Scotia* observers were able to

clockwise, remember, in the northern hemisphere, counter-clockwise in the southern. It follows, then, that north of the line the winds in an anti-cyclonic area are north-east and west; south of the line, they are south-east and west. Try to fix it this way: In the North Atlantic and North Pacific there are strong westerly winds; then the Horse Latitudes, then the north-east Trades. The Doldrums divide the hemispheres. Then come the south-east Trades, the calm belt of Capricorn (equivalent to the Horse Latitudes), and again strong westerly winds in the Southern Ocean to match those of the north. Only these of the south are the brave west winds of the Roaring Forties, having nothing to hinder or hamper them. And they blow and they blow, year in, year out, the grandest and the mightiest of all the beautiful rhythms in the veil on the face of the earth. There " the winds howl and the seas roar " in unending cadences. " The billows there lift themselves up in long ridges with deep valleys between them. They run high and fast, tossing their white caps aloft in the air, looking like the green hills of a rolling prairie capped with snow and chasing each other in sport." I told you that Admiral Maury was worth reading. And now you can understand why sailing ships make the outward voyage to Australia by way of the Cape, and the homeward all the way round by Cape Horn!

Let us try to summarize the air-movements, now, to get a mental view of them in their main circulations, freed from the complications that inevitably arise when we have to connect them with other pictures. It is not easy, I admit, but I think this quotation from the distinguished American meteorologist, Cordeiro, puts it fairly simply: " With a stationary world, hotter at the equator than at the Poles,

demonstrate *meteorologically* the existence of Antarctic land-masses, at that time unconfirmed; another, the prediction, subsequently justified, that the observations carried on in the Antarctic would be found to have a definite bearing on the condition of the monsoons in India.

the circulation would be along the meridians. With a rotating world, the deflecting force . . . introduces east and west components, which result in the breaking up of what would otherwise be a simple circulation into practically independent fractions separated by parallels of latitude. In other words, instead of a single circulation, there are several practically independent circulations. It is fortunate that this is so, for if the propelling forces which depend upon the differences of temperature were united along one line and summed together, such a blast would result, notwithstanding friction, that the world would be uninhabitable."[1]

Have I said enough to suggest that the rhythms of the winds provide interesting material for study? Such study is an intimate part of oceanography. For the air weighs upon the oceans, moves and directs their waters, whence new tunes and different measures emerge. It follows that the exploration of the atmosphere goes hand in hand with the exploration of the deep; it is as necessary to sound the one as the other; the meteorologist's kites and balloons are of equal value with the deep-sea sounding gear and thermometers.

Eight, nine, ten miles up—50,000 feet—the instruments search almost on the outer fringes of the atmosphere. There is a wonderful device (with the nasty name of meteorograph) which makes simultaneous records of temperature and pressure, from which the height at any moment can be deduced. This instrument goes exploring on its own account with the assistance of a pair of sounding balloons. A big balloon filled with hydrogen leads the way. Attached to its rope, at a little distance, is a smaller balloon. Then comes the meteorograph, and below that a float capable of supporting the weight of the instrument in the sea. Up, up go the balloons, lost to the earth. Yet not lost, for there comes a moment in the ascent when the big balloon, that soared

[1] Cordeiro: *The Atmosphere; its Characteristics and Dynamics.*

heavenwards so gaily at the rate of some 700 feet a minute, can no longer resist the change of pressure. It bursts, at a height of 40,000 to 50,000 feet, or thereabouts. The little balloon cannot alone support the weight of the instrument, which therefore falls, until the anchor-float touches the sea. Relieved of that much weight, the little balloon takes charge again, and holds the meteorograph well above the water until such time as it can be rescued by the ship that has followed it. The balloon takes about an hour to go up and an hour to come down. Just a pleasant little excursion!

I often think it is rather strange that most people regard air as imponderable. If we want to emphasize the lightness of a thing, we say of it that it is " as light as air ". Of course, air is light—compared with lead; but those whose business it is to design aircraft, or racing yachts, or big buildings—motor-cars, even—know that it really weighs a good deal. Well, a cubic mile of it at sea-level weighs five million tons. And when that air is set in vigorous motion, as in a gale of sixty miles an hour, you can hardly wonder that things get blown over. Actually, the pressure of the air at that speed is equal to rather more than 11 lb. on every square foot of resisting surface; so that an object of 100 square feet is pressed upon with a weight of half a ton!

We all know something of the driving force of wind; we have all chased our hats in it, leant our weights against it, fought it on foot, on bicycles; we have ruefully thought of the extra petrol needed to drive our cars through it. Those were extra special winds, storms, gales. True, but the hurricane, the Roaring Forties, and Coleridge's " meadow gale of spring " are different only in degree. Very few of us, happily, have had experience of wind at its worst, than which there is nothing on earth more terrifying. The travelling whirlpools of rotating air *we* call gales, the tornadoes of America, the hurricanes of the West Indies, the cyclones and typhoons of

the Indian Ocean and China Seas, are the same thing with different local names. They do not always arise from the same cause,[1] they vary in intensity, but they mightily influence the waters over which they ride. They may make the sea merely horribly rough, or they may drive before them a veritable wall of water high enough to devastate coasts and overwhelm low islands. Always the low pressure in the centre of a cyclone of any intensity sucks up the sea in a lump. It is this suction of the whirling, ascending air that often does more damage than the actual force of the outer air currents, though they blow at a hundred miles an hour or more. It can pull buildings up by the roots and carry them high into the air, or by reducing the air pressure around them, causes them to burst outwards. There is a splendidly graphic picture of a hurricane in Richard Hughes's fine pirate yarn—the high wind of *A High Wind in Jamaica.* There's *Typhoon*, the finest description of a sea storm that has ever been written—a masterpiece that stands alone; and you probably remember poor Dauber's storm. But I am going to close this chapter with a quotation from what is, of its kind, the best picture of the rhythm and beauty, the calm and the violence, of an American cyclone. This word-cameo, clear-cut, exact, is Lafcadio Hearn's description of a hurricane on the Louisiana coast in the Gulf of Mexico:

"Then one great noon, when the blue abyss of day seemed to yawn over the world more deeply than ever before, a sudden change touched the quicksilver smoothness of the waters—the swaying shadow of a vast motion. First the whole sea-circle appeared to rise up bodily at the sky; the

[1] Travelling cyclones are generally eddies formed at the junction of cyclonic and anti-cyclonic (i.e. equatorial and polar) air currents travelling side by side. Such eddies may be large or small in area, but they are always circular or elliptical, sometimes breaking in two. The speed at which the eddy—the storm as a whole—travels, and the speed of the wind within the cyclone, are very different things.

horizon-curve lifted to a straight line; the line darkened and approached—a monstrous wrinkle, an immeasurable fold of green water, moving swift as a cloud shadow pursued by sunlight . . . it curled slowly as it neared the beach and combed itself out in sheets of woolly foam with a rich roll of whispered thunder."

Thus Hearn pictures the prelude. This "swaying shadow of a vast motion" is the coming of the advance waves, the heralds that always run before the cyclone. Many times the unruffled sea heaves so, in regular cycles of mysterious undulations. There is not a cloud in the sky,, not a breath of wind. You might have fancied the sea had been upheaved from beneath. All day the sun stares from violet heights, devoid of cloud or mist, but at nightfall there appears a bridge across the sky, a beautiful arch of cottony pink vapour, and as the sun goes down, up comes the storm.

"Then the wind began to blow; it blew from the north-east, clear, cool. It blew in enormous sighs, dying away at regular intervals, as if pausing to draw breath. All night it blew; and in each pause could be heard the answering moan of the rising surf—as if the rhythm of the sea moulded itself after the rhythm of the air—as if the waving of the water responded precisely to the waving of the wind—a billow for every puff, a surge for every sigh."

All night it blew, and all next day; and the next, with one increasing fury the gale roared on its way and the colossal breakers crashed on the beach, twice the height of a man. The next evening brought with it no respite, but—"a sinister apparition looming through a cloud rent in the west—a scarlet sun in a green sky. His sanguine disc, enormously magnified, seemed barred like the body of a belted planet. A moment, and the crimson spectre v ished and the moonless night came". It was a tragic night indeed for that coast. The wind, now risen to one huge persistent

howl, lifted roofs and overthrew trees. Cottages began to rock and then to crumple up. Many inland country folk, in terror of the storm and of their isolation in palpably insecure farms and hamlets, fought their way to the big seaside town before which Hearn stages his story. There the big hotels, the substantial houses, the lights, the people, gave a new courage and confidence. In the great hall of the chief hotel 400 guests were dancing.

"Night wore on; still the shining floor palpitated to the feet of the dancers; still the pianoforte pealed, and still the violins sang and the sound of their singing shrilled through the darkness in gasps of the gale.

"'Waltzing,' cried a sea captain, 'God help them! God help us all now! The wind waltzes to-night with the sea for his partner!'

"Oh, the stupendous *Valse Tourbillon*! Oh, the mighty dancers! From the north-west to the east, from east to south-east, from south-east to south, then from the south he came, whirling the sea in his arms. Someone shrieked in the midst of the revels—some girl who had found her pretty slippers wet. What could it be?" What indeed could it be, but the dreadful piled-up mass of water, the cyclone wave carried along by the centre of the cyclone? Up it came, rising over the land, spreading over the level planking of the dance hall, swirling irresistible about the feet of the dancers.

"What could it be? All the land had begun to quake, even as but a moment before the polished floor was trembling to the pressure of circling steps; all the building shook now; every beam uttered its groan. What could it be? There was a clamour, a panic, a rush for the windy night. Infinite darkness above and beyond, but the lantern beams danced far out over an unbroken circle of heaving and swirling black water. Stealthily, swiftly the measureless sea-flood w rising.

" For a moment there was a ghastly hush of voices. And through that hush there burst upon the ears of all a fearful and unfamiliar sound. Vastly and swiftly, nearer and nearer it came—a ponderous and unbroken thunder-roll, terrible as the long muttering of an earthquake.

" Then arose a frightful cry—the hoarse, hideous, indescribable cry of hopeless fear—the despairing animal cry man utters when suddenly brought face to face with Nothingness, without preparation, without consolation, without possibility of respite—*sauve qui peut.*

" And then—then came thundering through the blackness, the giant swells, boom on boom! One crash! the huge frame building rocks like a cradle, see-saws, crackles. Another! Chandeliers splinter, lights are dashed out; a sweeping cataract hurls in; the immense hall rises, oscillates, twirls as upon a pivot—crepitates—crumples into ruin. Crash again. The swirling wreck dissolves into the wallowing of another monster billow; and a hundred cottages overturn, spin and eddy, disjoint and melt into the seething.

" So the hurricane passed, tearing off the heads of prodigious waves, to hurl them 100 feet in the air—heaping up the ocean against the land—upturning the woods. . . . Before New Orleans the flood of the mile-broad Mississippi rose six feet above high water-mark. . . . The billowing tide rushed unrestricted from the Gulf, tearing and swallowing the land in its course—ploughing out deep-sea channels where herds had been grazing but a few hours before—rending islands in twain—and ever bearing with it through the night, enormous vortex of wreck and w drift of corpses."

CHAPTER IX

Where the Ocean Rivers Run

Every little puff of air sets in motion a patch of water. That statement explains not only the turmoil of the waves but the origin of the great currents—the " rivers of the ocean ". But it is not really quite as obvious as it looks. Not very long ago the regular ocean streams, ever flowing in well-defined channels—really like rivers—were thought to be impelled by a force originating in the unequal distribution of temperature. It was demonstrated that the warm waters of the tropics flowed polewards as surface currents, while the cold waters of high latitudes rolled towards the equator at a lower level. That simple theory was accepted for want of a better, but it left a great deal unexplained, and it is only in recent times that the systematic investigation of the depths with water-bottle and thermometer has enabled oceanographers to reveal what really happens.

I think it was in Chapter IV that the term " sea-level " came up for criticism. Except where a " mean " has been assumed for purposes of measurement, there is not one sea-level, but many. In fact, the sea is never level, anywhere. The land masses draw the waters up to them, as we saw; and it is obvious that if the atmosphere weighs upon them in one place with a pressure of 15 lb. to the square inch, and in another place with a pressure of 14 lb., the greater weight will heap the waters up under the lesser weight, in an attempt at equilibrium. Wherever the barometer goes

down at sea, up comes the sea-level; wherever the barometer goes up, the greater weight of air depresses the sea. There is a rule for this: mercury is about 13·6 times as heavy as water, consequently, if the barometer suddenly rises by one inch the level of the water will be lowered by 13·6 inches. In other words, a current will flow away towards the region of low pressure until the general level is restored.

There are also differences of level due to differences of temperature. Heavy and continuous rainfall adds to the sea water that must "run downhill" somewhere, and the discharge of great rivers and, in the summer, the melting of vast masses of ice in polar regions are other influences that have a share in pulling and pushing and otherwise disturbing the general level of the surface of the sea. Clearly, they all contribute to sea movements, setting up stream and counter-stream. But commanding them all and making them little in comparison is the breath of the atmosphere. The swaying rhythms of the air, the great Trade Winds we followed in the last chapter, literally push the waters forward, piling them up against the continents so that they have to bend upon themselves, flowing and returning in constant streams.

Shall we have a few moments with the map again, to see how the permanent currents of the air encourage the permanent currents of the waters? Suppose we start with the Atlantic and fix our minds on the wide stretch of ocean between Africa and South America, in the region of the south-east Trade Winds. A wind blowing from south-east, blows towards the north-west; and the waters of the South Atlantic are therefore propelled in that direction. But not *en masse*; the temperature of the sea is highest in the belt about the equator, and from that it follows that there must necessarily be differences of density between the body of water constituting that belt and the bodies of water in the sub-tropical zones to north and south of it. Warm water

being lighter than cold, it rises to the surface, the colder, denser water sinking and flowing under it. Flowing, because the warmer water must go somewhere. There are formed, in short, two currents: an upper warmer one above a lower cooler one. There are other causes affecting the weight of the water, changes of salinity, and so of density, due to rainfall, to evaporation and so forth—but at the moment we must keep our minds on the Atlantic under the Trade Winds. These winds, recollect, are blowing from, roughly, the tropic of Capricorn north-westerly to the Doldrums and —roughly again—from the Tropic of Cancer south-westerly to the Doldrums. These two great wind systems are clearly for ever pushing the oceans equator-wards. But the whole wide belts of the oceans on which they exert their frictional force do not move to the command throughout their whole extent. If they did, there would be, not currents, but a mighty banking up against the continents.

We must keep the domestic hot-water system in mind. It does not put a very exacting strain on the imagination, nor does it strain too much the science of the parallel, to think of the oceanic circulation as a gigantic hot-water system somewhat similar to that serving the bathroom and the scullery sink. Instead of iron pipes conveying separate streams of hot and cold water from cistern to boiler and back again, imagine channels formed by the alterations in the molecular activity in the water itself. In the equatorial belt is water with a surface temperature of over 80° F., on either side of it water of gradually diminishing temperature. Now, by reason of its superior temperature this equatorial water has greater volume. Here is a "head" of water—water standing at a higher level than the surrounding ocean. As I said before, it must flow somewhere, and it therefore spreads out upon the cooler waters coming to take its place and becoming warmed in their turn. Actually, it induces

a circulation into which the coldest waters of all are drawn; the northern and southern seas sink down towards the ocean-floor, to take the place of the warm seas of the tropics.

But if what I have indicated were all, there would be but two simple circulations—from the equator to the south polar regions and likewise to the north polar regions, and back again in each case. This is where the Trades come in. The initial movements of the water, brought about by the differences in density, are taken in hand and directed by the winds. The head of warm water on the southern side of the equator has now become the southern equatorial current. The south-east Trade Wind drives it up against the northern part of South America. We are confining ourselves to the Atlantic, for the moment; but if you look at the southern equatorial current in the map on page 116 you will see that it has a south-westerly trend instead of the north-westerly one would expect from the direction of the wind. A moment's thought will explain the anomaly. Remember that every moving body upon the surface of the earth comes under the influence of its rotation and that the "drift" is with the sun; it deviates to the left in the southern hemisphere and to the right in the northern. This deflection becomes more apparent in the currents of the northern hemisphere, but it applies equally to all oceans.

The southern equatorial current divides into two off Cape San Roque on the coast of Brazil, one part sweeping down South America, the other turning northwards towards the Caribbean Sea. The southern part, now known as the Brazil current, presently turns *eastward* at the bidding of those great westerly winds, the Roaring Forties. And so this once warm current from the equator makes the full circuit of the South Atlantic, growing colder all the time. It flows northwards up the west coast of Africa in company with a cold current, the Benguela current, which is caused

by up-welling of deeper water to replace that driven from the surface by the south-east wind. Then it resumes its westerly course as the southern equatorial current.

This circular movement is characteristic of the Atlantic, Pacific, and Indian Oceans. In each case, the uprisen equatorial waters are driven westwards by the Trades, until, on reaching the continents, the equatorial current divides in two streams, one flowing northwards along the coasts, the other southwards. Then, as they come under the influence of the opposite winds north and south of the calm belts of Cancer and Capricorn, they change their respective directions and the rotatory movement is complete. Each ocean is in effect a gigantic " water-whirl ". Now, look at the diagram again and this very interesting and significant fact will occur to you; each water-whirl circulates around the great anti-cyclonic areas we investigated in the last chapter. But it should be explained that the circular system in the Indian Ocean does not quite tally with the others. Here there is not one water-whirl but two; and the more northerly of these is modified and guided by the change of the monsoons. In the Southern Ocean, again, there is a steady easterly drift. What else should we expect from the " Brave West Winds " and the absence of land?

We left the southern equatorial current at the point where it divided at Cape San Roque; we may now see what happens to the northern branch. Urged to the *right* by the spin of the earth, it flows along the north-western coast of South America, being presently drawn in between the mainland and the long chain of the West Indies. There, for a moment, we must leave it, while we return to the equator. Let us stick to the Atlantic, because it is simpler to take a single ocean by way of illustration, and we know that the laws applying to one apply to the others. We have so far considered the warm water flowing out *south* of the Doldrums. But it flows

out to the north as well, and as the northern equatorial current it is driven westwards by the Trades of the northern hemisphere—the north-east Trades. Remember the rotational deflection to the right, and picture this current—the mother

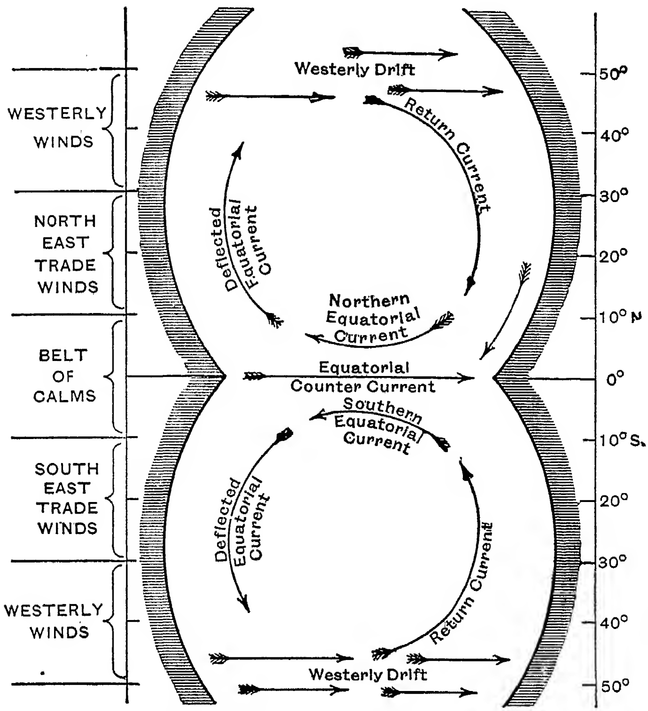
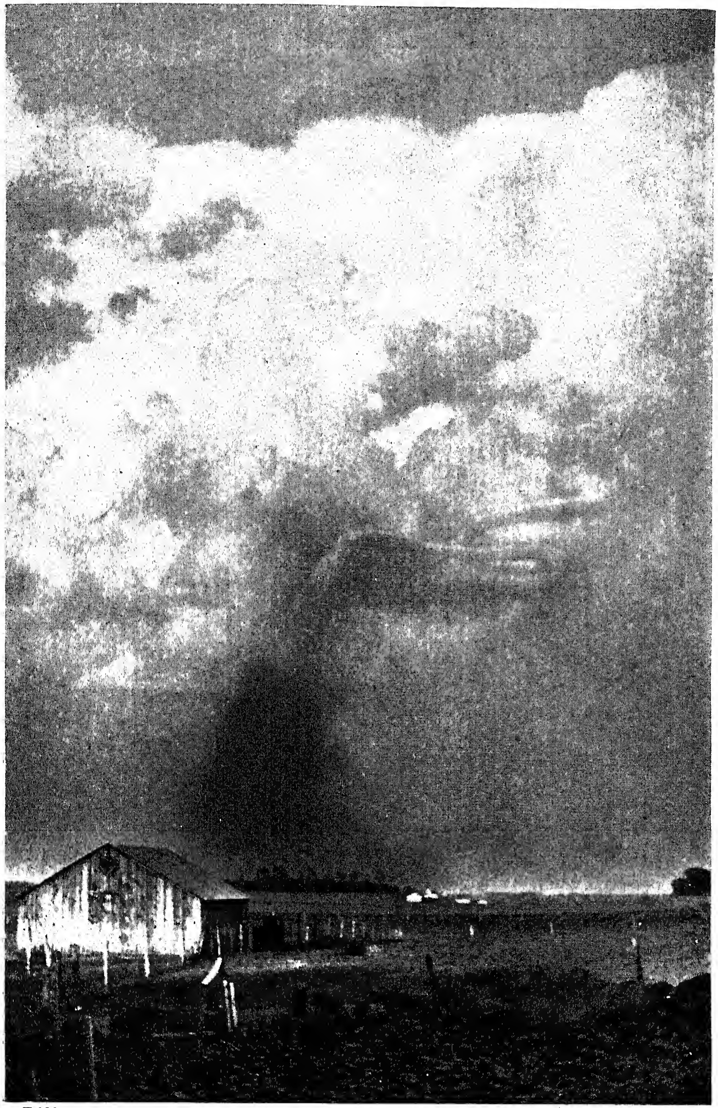


Diagram of the Typical Oceanic Circulation and its relations to the Winds

of the North Atlantic circulation—sweeping up towards the West Indies. It is driven partly inside them and so greatly strengthens the northern tongue of the southern equatorial current already flowing through the Caribbean Sea. Still north-westwards it flows, until it fetches up in the Gulf of Mexico, to form the mainspring of the Gulf Stream.

It is a noble and splendid thing, this Gulf Stream—a gigantic stream indeed. The Trades pile up the two equatorial currents in the Gulf so that they stand considerably above the level of the cooler ocean outside. Out comes the great warm river; it bends round the western end of Cuba, issues through the Straits of Florida—its only outlet. The river of rivers, there is none to match it (though the Pacific has its counterpart in the Kuro Siwo or Japan Stream), and out it swirls, fifty, sixty, seventy miles wide, three hundred fathoms deep, with a speed of over a hundred miles a day. Yet its initial greatness is short-lived. As it travels along the United States coast it becomes broader, shallower, more and more sluggish, and always cooler, until off the Grand Banks of Newfoundland, it turns eastwards, and proceeds to cross the North Atlantic. But not as the Gulf Stream. It is that no longer, but has merged into the North Atlantic Drift, aided and abetted by the west winds. The North Atlantic Drift forms two branches; a southern branch which bears south off the coast of Spair and eventually rejoins the north equatorial current; the northern branch is more interesting and more important. To follow it, we must return to the Gulf Stream.

It is a very marvellous thing, that mighty river of the Atlantic; warm, very salt, very clear, very blue. Blue is the natural colour of sea-water. The blue rays of light are not all absorbed by the water, but reflected back, the red rays being absorbed ten times as readily as the blue. On this matter of colour Sir John Murray says: "Within the thirtieth parallels north and south of the equator the colour is a brilliant ultramarine, and to the south of lat. 30° S. it changes rapidly to a deep indigo, which continues as far as the Antarctic Circle, where it changes to olive-green. Variations in colour may be due to materials in suspension and solution; thus in the neighbourhood of coral reefs the water



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A TORNADO BREAKING UP

From a photograph taken by Miss Lusille Handberg in Minnesota, U.S.A.

Facing page 112.

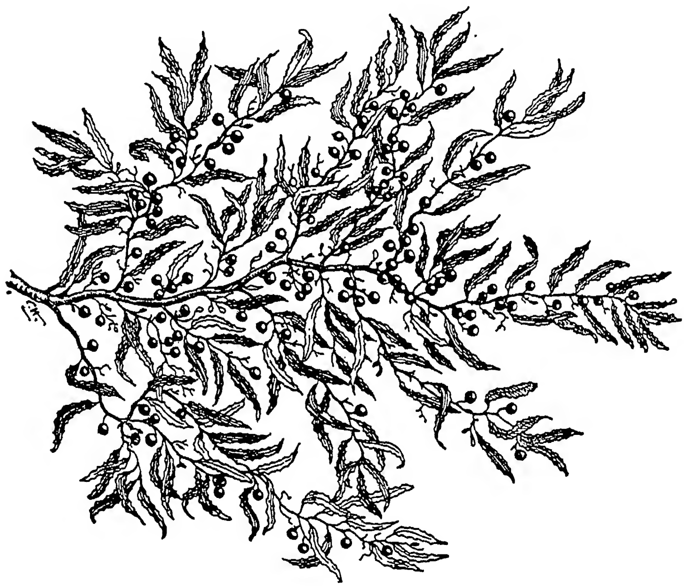
is usually of a deep shade of blue, ascribed to calcium carbonate in solution, while the green colour of the water in the far south is due to the abundance of diatoms and other minute plants."

The Gulf Stream is the bluer by contrast with the greenish or yellowish-green of the water flowing on either side of it. Long after its speed has declined to the point at which it almost ceases to be a current, you can trace it—if you happen to be sailing on its edge—by its colour and clearness. To east of it is the yellow of the Gulf Weed, to west of it, the cloudy, greenish, littoral water full of American mud and sand. I used to think how lucky the Americans were to be able to step off their shores into the nice warm water of the Gulf. There was in that a tinge of envy based on ignorance, for they can't. Between their coast and the Gulf Stream is a strip of water so narrow that the map does not show it; and instead of coming up from the Gulf, it is a downward current from Labrador. They call it the *Cold Wall.*

Between the northward-trending flow of the Gulf Stream and the branch of the North Atlantic Drift that makes a wide sweep from Newfoundland eastwards and then south across the ocean to the coast of Africa—lies the strangest backwater in all the seas. Draw a triangle in mid-Atlantic, joining the Azores, Cape Verde Islands, and Bermuda; there, nearly in the heart of the water-whirl, lies the Sargasso Sea—" the floating meadows ". It is difficult to convey any idea of the immensity of the gigantic island of weed that is for ever and ever drifting now this way, now that, in this ocean backwater. Columbus found his three ships involved in it on 16th September, 1492, and spent some days in extricating them from the new terror that threatened entirely to undermine the discipline of his already mutinous crews. He thought it land, and was much disappointed to find it was only a vast mass of floating weed. In all the four hundred

years since Columbus discovered it, the sea of matted weed has not altered its mean position.

The origin of *Sargassum bacciferum*, the floating weed that gives its name to the Sea, is still a scientific puzzle. It is a sea mystery. It is but one of many species of sargas-



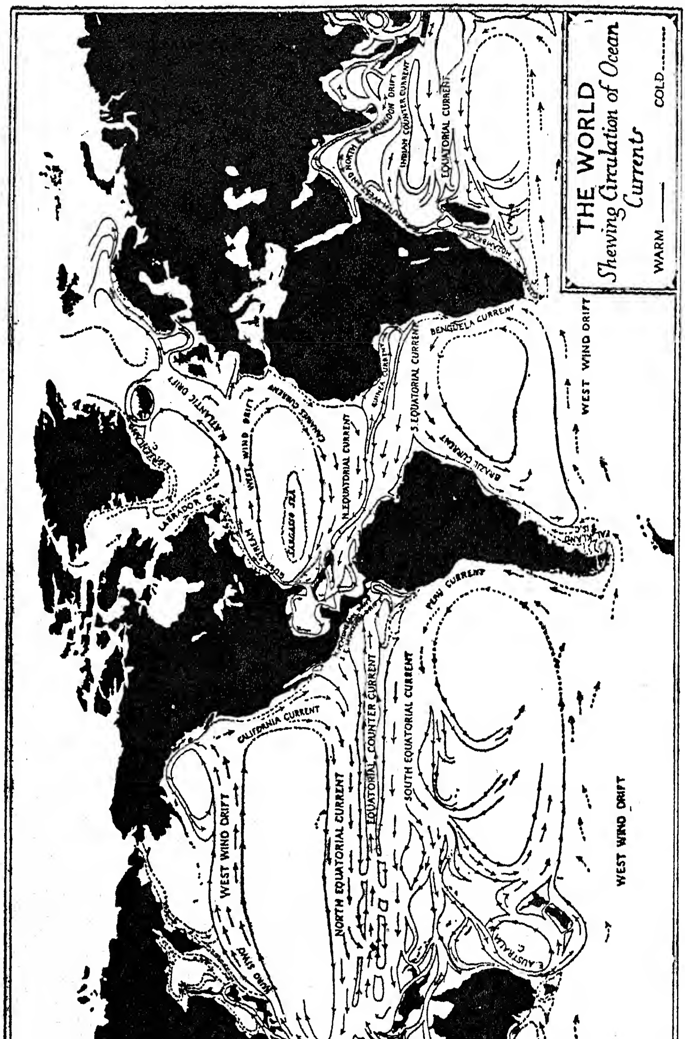
Sargassum bacciferum

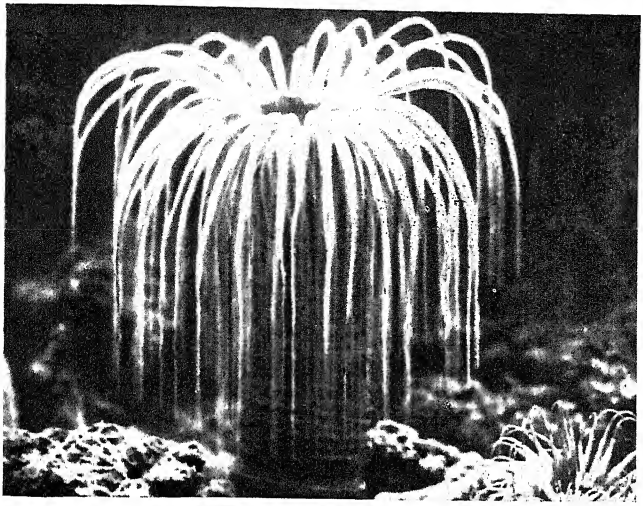
sum; a rather graceful plant, yellowish in colour, its long fronds covered with multitudes of small " leaflets " and berry-like air-buoys. Fields of this plant there are, of thousands and thousands of acres, of incredible denseness, converging, drifting apart, colliding, dividing, sometimes getting trailed out by the Stream and the wind in gigantic yellow ribbons across the broad heart of the Atlantic. The Gulf Weed has no organs of reproduction and is always found floating, but a very similar species grows attached to

rocks. Now, the puzzle is this: Has the Gulf Weed always been floating, or was there ever a period in its history when it grew attached to rocks like its present-day relations? Or did it once upon a time decide that a roving life was better than a settled one? Or does it really conform to orthodoxy, becoming detached like other seaweeds from perfectly respectable reefs in some unknown locality? If you can find a tame algologist, ask him these questions, and I am sure he'll expand!

The weedy islands are densely populated. Creatures of many strange races inhabit the tangled depths and claim this world as their own. But though the "ground" looks substantial enough to walk on, to build houses on, it is not really as thick as it appears from a distance. In the oldest of the old sailing days, no doubt, when ships had none but clumsy square sails more like sacks than anything else, corpulent beam and bluff bows, they may have stuck for days and weeks before getting clear of the Sargasso Sea. But you are not to believe the terrible stories of the ships that are said to have drifted and drifted without possibility of escape until, with their crews dead of hunger and thirst, they at last blew clear in some violent storm. There are tales of good ships that have been carried by the unvarying currents to European coasts, unmanned, but bestrewn with the tell-tale weed of ill-omen. One cannot say such things have never been, or that they could not be, but it is wise to regard such stories as in the main more imaginative than truthful. For on such horrors the *Michael Sars* expedition of 1910 was able to throw a searchlight of scepticism.

We have lingered overlong in the water of the Gulf Stream. This great surge of the tropical seas through the Straits of Florida holds so much that is fascinating; it is the sea picturesque, the stage splendidly set for the prelude of the perpetual motions of the Atlantic. I know it seems


THE WORLD
Shewing Circulation of Ocean Currents
WARM
COLD
WEST WIND DRIFT
BENGUELA CURRENT
S. EQUATORIAL CURRENT
GUINEA CURRENT
BRAZIL CURRENT
PERU CURRENT
SOUTH EQUATORIAL CURRENT
EQUATORIAL COUNTER CURRENT
NORTH EQUATORIAL CURRENT
CALIFORNIA CURRENT
WEST WIND DRIFT
WEST WIND DRIFT
N. EQUATORIAL CURRENT
CANARIES CURRENT
WEST WIND DRIFT
N. ATLANTIC DRIFT
GULF STREAM
SARGASSO SEA
LABRADOR C.
E. AUSTRALIAN C.
KURO SIWO
INDIAN COUNTER CURRENT
EQUATORIAL CURRENT
MONSOON DRIFT



"Grafia" Copyright.

A sea-anemone of almost artificial perfection

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"Mondiale" Copyright.

A sea-anemone as if relaxed in sleep, its tentacles like petals stirred by the breeze

an anti-climax even to think of our own cold Northern Ocean. I would like you to think of the great Gulf Stream flowing eastwards over the Atlantic that it might bathe our own fortunate isles with its warm pellucid waters. I would like to tell you that it does so favour us; but this is a veracious book and—alas for our illusions and the geography books of a generation ago—the Gulf Stream does nothing of the kind. It ignores the British Isles, it leaves them cold.

You remember that we followed the Gulf Stream as far as the Banks of Newfoundland, where on page 112 we left it to swing eastwards in about lat. 40, as though to approach our own shores. But it tails out sadly—it has merged into the *North Atlantic Drift*. Of the two branches of the Drift we traced the southern down the coast of Africa so as to complete the circuit. The northern, being our own particular branch, deserves a moment's study, especially as we want a slash at the great Gulf Stream fallacy. And this is where the significance of the water-bottles and thermometers comes in, for the North Atlantic Drift (as the cooler, wider, slackened remains of the Gulf Stream should now be called) undergoes some very subtle changes of temperature and salinity. Just where the Gulf Stream turns east it suffers a physical shock from the icy waters coming down from the Arctic Ocean. The southward-flowing Labrador current brings its icebergs to cool the warm current from the tropics. The upper layers of the Gulf Stream become colder and colder, the waters of which consequently sink, their place being taken by the relatively warmer water from beneath. This in turn becomes cooled; and the melting ice, being less salt than the Gulf Stream waters and consequently lighter, flows out and still further cools the surface. The wonder is that there is any warm water left. But the Gulf Stream has had such a mighty start and represents so great a volume of water, that though it ceases to be a current in

the strict sense, a mass of its relatively warm water is left to be drifted eastwards by the west winds blowing out of the northern anti-cyclone. A remnant of what was once the great warm stream blows up against the British Isles; another remnant penetrates the Norwegian Sea and finally sinks to the bottom off Spitzbergen. But nowhere in the North Atlantic is the water warm enough to have any influence on our climate. Every summer three great currents coming down from the Arctic Circle pour into the North Atlantic large quantities of icy water, the effect of which is to chill our summer instead of cheering it. Fortunately for us, the conditions are better in winter, when the ice is safely under lock and key. No; the Gulf Stream has next to no influence on our climate. We must thank the winds for what we enjoy—the nice wet, west winds.

To what depths do currents flow? That simple question is really a very complicated one to answer. The investigations of oceanographers—their water-bottles, current-meters, and thermometers—have revealed a complex system of underwater circulation, quite distinct from the surface movements of the ocean. It is now known that there is an intimate connexion between the flowing of the underwater rivers and some of the most mysterious rhythms of sea-life. Much still remains to be explained, but it is thought that the distribution of marine animals, their abundance in those waters, their scarcity in these, is largely influenced by the currents flowing beneath the surface. Current investigations have shown that the surface currents are shallow—a few hundred fathoms deep only. Sometimes they are much less than that. Every moving body of water imparts by friction some of its movement to another body of water of different density in contact with it. The density of sea-water changes very readily and there are many influences at work to change it, the result being the generation of a

very bewildering system of deep-water currents. It is said that in the Atlantic there are at least four definite currents at different depths, and these distinct water-masses, each with its peculiar temperature, salinity, and even animal life, still demand exact and systematic study before they can be fully understood.

The salinity of the ocean has a very important bearing on the density of the water, as we saw in Chapter V. If you bathe in the Baltic you will sink more easily than in the English Channel—it is said that the waters of the Gulf of Bothnia are sometimes fresh enough to be drinkable, but I imagine one would need to be very thirsty! While in the Mediterranean you can float more easily than in the English Channel, and still more easily in the Red Sea, if you don't mind the water being at blood heat. In enclosed seas like the Mediterranean and the Red Sea there is so much evaporation that the water becomes highly concentrated, and stands at a lower level than the ocean outside. That is why, in the case of the Mediterranean, there is a strong current eastwards through the Straits of Gibraltar. The higher waters of the Atlantic flow *into* the Mediterranean; and although the Mediterranean waters are hotter than the sea outside, and might on this account be thought to be lighter, they are also very, very salt from the constant evaporation, and the density due to saltness more than counteracts the expansion due to temperature. They sink to the bottom and form an *outward*-flowing current beneath that coming in from the Atlantic. Much the same sort of thing happens at the eastern end of the Mediterranean Sea, the heavy salt water flowing on the bottom through the little Sea of Marmora into the Black Sea. The waters of the latter, freshened by many great rivers, form a surface current that flows into the Mediterranean.

CHAPTER X

The Rhythms of the Tides

We may imagine the wonder and dismay of the adventurous seamen of the Mediterranean when first they sailed through the swirl of the Straits of Gibraltar and so came upon the phenomenon of tides. Their own sea is nearly tideless, and as they crept up the coasts of Iberia and France and so into the Narrow Seas, or as they sailed down Africa, they would come under the spell of a mystery that never fails to stir the imagination. Swift currents they knew, such as those in the Straits of Messina. Had they not Scylla and Charybdis? But tides—the covering and laying bare of stranger coasts that the sea embraced, repudiated and embraced again in a manner most bewildering! The Romans, the Greeks, the Phœnicians, having no tides of their own, or next to none, gave little heed to the phenomenon. But the nations of the northern seas, where the tides swirled about headlands and flowed up and down bays, and by turns made inlets and estuaries wide breadths of water or fields of glistening sand or weed-draped rocks, found in the daily rhythms food for thought and wonderment. It has been suggested that these northern peoples—Franks and Saxons, Danes and Norsemen—failed to connect the tides with the influence of the moon. That is incredible; no one could live by the sea for a year without discovering for himself that new moon, full moon, and quadrature was, each phase, a mysterious power to lead or restrain the raising up and

drawing back of the water. No; they were content to ascribe the command of the ocean to supernatural powers—" thus far shalt thou advance!" Yet doubtless they understood the intimacy of moon cycles and sea cycles; being sailormen, they probably understood it fairly well.

It is odd how little most of us really know about these most astonishing water movements. They put us in touch in so strange and yet so direct and intimate a way with the most distant ends of the universe. I don't mean in an abstruse mathematical sense; not in the complexities of tidal dynamics, but in the very simplest and most obvious of its visible rhythms. Most of us know that in some way the moon pulls the sea—and most of us are content to leave it at that! True enough, the moon *does* pull the sea, and every particle of earthly matter—solid, liquid, or gaseous as well. So there are not only sea tides, lake tides, river tides, but earth tides, and tides in the ocean of air; definite, rhythmical oscillations of the atmosphere that are not merely theoretical but revealed in regular variations in pressure.

The earth makes a complete revolution in twenty-four hours and fifty minutes. Twice in that period the coasts of the Atlantic, Indian, and North Pacific Oceans undergo a very remarkable experience. Once in a little more than twelve hours (twelve hours, twenty-five minutes, theoretically) the sea comes up the shores, pressing into inlets and estuaries, as though with a sudden eagerness to caress the land. For a trifle over six hours the onward movement grows; at the climax of the flood, a little pause, while land and sea rejoice in their closest union. Then back the waters run, sometimes swiftly as if with a message for the horizon, sometimes sluggishly, reluctantly. And the shining sands come singing again to the world—with their strange little musical hiss that is like no other song upon earth—and islands rise up out of the flood, with lakes and lagoons and

eager impetuous rivers tearing through a new landscape. So ebbs the tide, running seawards for a trifle over six hours, and then ensues the next pause, a momentary state of rest —" slack water ".

That is the daily rhythm, the flowing and ebbing we are all familiar with. A little closer observation reveals a fortnightly rhythm as well, and another one every half-year. The moon makes a complete revolution of the earth in a little under twenty-eight days.[1] Twice during that period—when the moon is new and a fortnight later when it is full—the tides rise to a higher level and recede to a lower one. At every new moon there is one of these very high or spring tides. As the moon begins the phase of her first quarter, the range of the tidal level grows less and less as she develops in quadrature, until the smallest or neap tides are reached about a week after the new moon. Then for a week they wax in sympathy with the waxing moon. Full moon brings spring tides again, then the force of the tides wanes with her waning, until they have once more declined to the spiritless neaps. New moon stirs them again to rise higher and fall lower; and so the cycle runs with unvarying regularity—spring tides whenever the moon is new or full, neap tides whenever she is in quadrature. A moment's thought shows that the variations in the tides cannot be due to the moon's unaided influence. Her power to shine on us, to show us this week her crescent, next week her quarter, and a week later her full face arises from her motions relatively to those of the earth and the sun. Clearly, the sun has a hand in the business of the

[1] The actual time is twenty-seven days, seven hours, forty-three minutes, eleven seconds. But the interval between one new moon and another is twenty-nine and a half days. This difference between the moon's *sidereal* period, as the shorter is called, and the *synodical* or longer period presents a little problem worth thinking about. It isn't as hard as it looks when you reflect that the moon's apparent movements are not only east and west, but north and south as well, and that they are measured by the sun, which also appears to move.

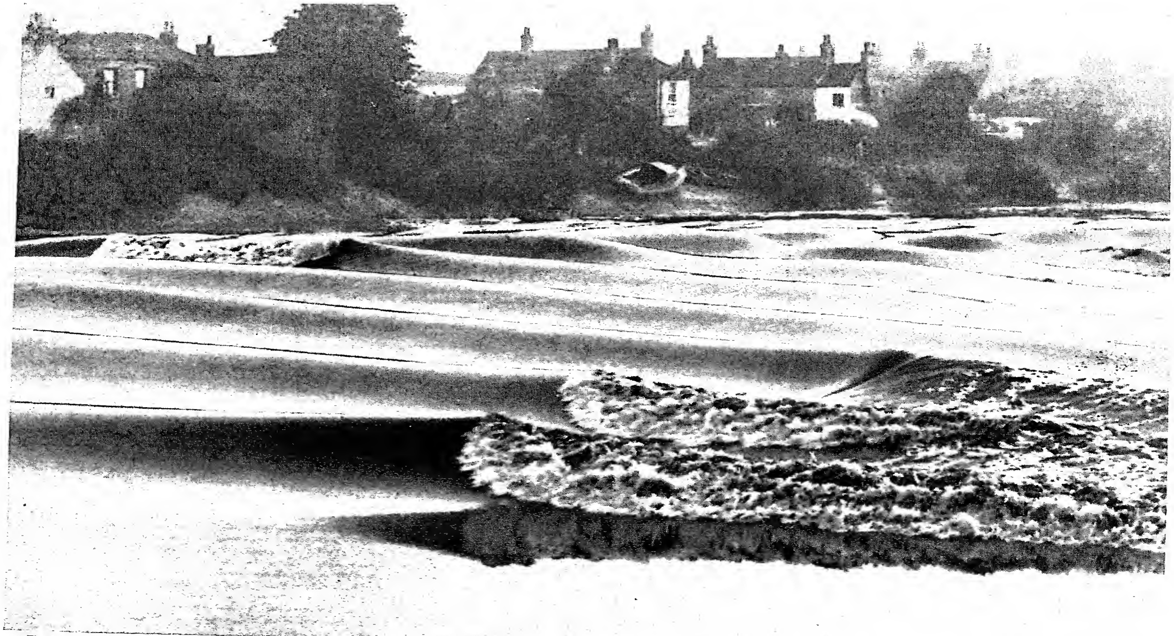
tides; and this becomes the more apparent the longer we watch the daily and fortnightly changes of the seashore. If we watch from winter to spring we find that at the time of the vernal equinox, when the sun in passing from south to north describes the circle of the equator in the heavens, the spring tides that fall then are unusually high; and if we watch for another six months, these extra high spring tides are found to occur again at the time of the autumnal equinox, when the sun is apparently moving from north to south. That seems definitely to establish a marked solar influence acting upon the more obvious lunar influence.

Such are the characteristic phenomena of the tides—their most forcible manifestations. If you have anything to do with coastal interests the tides mean a great deal to you. Whoever sails a boat or goes fishing, or owns property or cultivates land a little above the reach of the spring tides, knows the behaviour of the water from one year's end to the other. There is a famous and marvellous book called the *Nautical Almanac*, containing pages and pages of tables and calculations, based on astronomical movements for years ahead. From some of these tables the times and heights of the tides in any part of the world can be found for any date. The *Nautical Almanac* was first published as long ago as 1767, but for many years now it has been a Government publication, issued by a special office of the Admiralty. I suppose that this book, and two or three similar works published by foreign states, are the only publications in the world to be issued three or four years in advance of the year to which they refer—a rather strange distinction that has its origin in the inflexible exactitude of mathematics. The *Nautical Almanac* is the mariner's second Bible, but if he needs no more than information about tidal times and ranges he probably refers to simpler tide tables. The tides move with the regularity of the celestial motions. Spring tides at

any place occur always at the same hour; and this hour—the time of high water on the days when the moon is new or full—is called the *establishment of the port.* The tide is progressive; it moves along the coasts at a known speed, and high water at one point is followed by high water at another after a definite time interval. It is an easy matter to find the time of high tide at any place in the same seas if you know the establishment of the port at one place and the interval or *tidal constant* between it and the place you want. All good almanacs give tidal constants for all ports in the British seas.

I am going to try to make the origins of the tides clear. Let us try to reach out to the how and the why, and the tides, I promise you, won't be any the less picturesque and mysterious. Of course, if you know already, skip this. And if you don't like concentration, skip it, because we must try to get in contact with certain profound truths established by a certain profound philosopher named Newton. Kepler and Galileo both had a tilt at the tides, but the problem was beyond them. Galileo thought the water-wave might be due to the spin of the earth, but he had no great faith in his jump in the dark. It was left to Newton to lift the corner of the veil hiding the great secret. After him Laplace—" the Newton of France "—and the genius of Lord Kelvin d many another great scientist of our own era. But mark this, the light is not yet constant, clear. We do not know *all*, or nearly all; and if *you* have a mathematical flair, a taste for science on the grand scale, the remaining puzzles of the tides are intriguing enough to hold you in thrall until the day when the Royal Society or the British Association invites you to present your thesis—a most promising subject for study, I assure you!

The theory of the phenomenon of the tides starts from Newton's postulate, that every particle of matter in the



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E. W. Carter Copyright.

THE "ÆGIR" OF THE TRENT

A photograph of the wonderful tidal phenomenon which travels at a speed of about twelve miles per hour

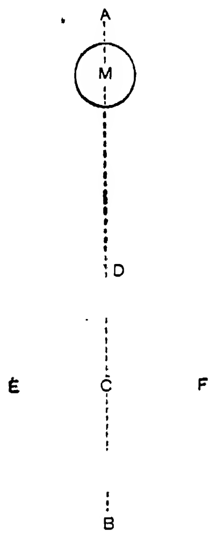
Facing page 125.

universe attracts every other particle, with a force varying inversely as the square of their mutual distances, and directly as the mass of the attracting particles. That is the foundation of the law of gravity. If it sounds complicated, think of it in this way. Here are two bodies of equal mass, whose power to attract each other at one mile apart is four times as strong as it would be if they were two miles apart, or sixteen times as strong as it would be if they were four miles apart. Or take another example; the particles of bodies A and B, of equal mass, have at any given distance relative intensity of attraction. At double that distance the intensity of attraction would be one-fourth, at three times the distance one-ninth, and so on. Distance, mass, and one other factor are necessary to complete the law of gravitation; every particle of matter in the universe attracts every other particle with a force *whose direction is that of the straight line joining their centres*. That is the universal law, often carelessly stated as explaining motion; it only explains the rules of motion—not the cause. Well, that's beyond us altogether—beyond science so far, in spite of a hundred conjectures. But the rules are sound enough; Newton did once or twice make guesses, put forth hypotheses that he couldn't prove, but in this case he applied proof. He made some observations and he did some sums, and he showed that the moon in its revolution round the earth is held in its orbit by an attraction which is exactly equal in force to that which brings a body to earth with an increasing impetus of about 32·2 feet per second.[1]

Such are the rules. Now let us see whether, without going into the mathematics of the subject, they will explain for us the rhythms of the tides. To do this without complications we may be allowed to stop the motions of the

[1] For simplicity's sake the modifications of the Newtonian law necessary to Einstein's theory are left out of consideration.

earth and the moon, for a moment—to hold them in our minds, quite still—the full moon glaring indignantly at her mother. The moon pulls and the earth pulls. Here is a sketch showing the position of affairs; M is the moon, C is the centre of the earth, AB is the straight line passing through their centres—the direction in which every moon-



particle and every earth-particle are exerting their peculiar attraction. The attraction is greatest at the point D, where I have shown a bulge of ocean. The land surface beneath it bulges a little too, but the crust of the earth is about as rigid as steel and won't be drawn sufficiently to measure. The fluid, mobile, fickle ocean responds to the gentle pull more readily. You might think, to look at it, that the moon was pulling the water towards it vertically, but its attraction isn't powerful enough for that. You can't lift the garden roller vertically off the ground with one hand, but you can probably pull it along the tennis lawn with one hand. Just so, the moon's attraction is strong enough to pull the seas in a horizontal direction towards her—from the sides of the earth E and E to the point nearest to her at D. There is the heaped-up water under the moon—and high tide at whatever meridian on the earth may chance to be represented by D. So far there is no difficulty. But there are *two* high tides every day, everywhere. If, keeping our minds for the moment on the point D, we now give the earth a complete turn on its axis C, the bulge at D gives us only *one* high tide in the twenty-four hours—which won't do. Now this is more difficult to understand, but the fact is this; when the waters of the ocean are heaped up at a

point nearest to the moon, they must inevitably be heaped up also at a point farthest from her. There are always two high tides—one on the hemisphere nearest to the moon, the other on the opposite hemisphere, and consequently two low tides simultaneously, at the points on the earth midway between them. Look again at the figure, and ask yourself why there should be a bulge of ocean at B as well as at D. Why isn't the water low at B as well as at E? Well, the force of attraction varies inversely as the square of the distance, and directly as the mass of the attracting particles. With those rules remembered, the twin high tides and the twin low tides become mathematical certainties.

The distance from the moon at the centre of the earth is 4000 miles greater than the distance at the point on the circumference nearest the moon (D). The waters are consequently attracted more per unit of mass than the earth beneath them, and become heaped up. At the centre of the earth the particles are attracted much less per unit of mass, and much less still at the point B on the opposite surface of the earth, which is *another* 4000 miles from the moon. The attractive force of the moon-particles acting along the line AB is inversely proportional to the square of the moon's distance. At any point on the earth's circumference *off* the line joining the centres of the moon and the earth, the greater force of attraction will be not towards the moon, but towards the earth's centre. At such points, therefore, the watery layer is *pulled inwards*, thus emphasizing the bulges at D and B. And at the farthest distant point on the straight line AB the water is being pulled *away* from the moon so that it becomes heaped up at B as at D, because the water there is attracted less than the solid earth. It isn't merely "left behind" at B. It becomes heaped up there, relatively to the centre of the earth, because the moon is there so far away that it has less influence than the gravi-

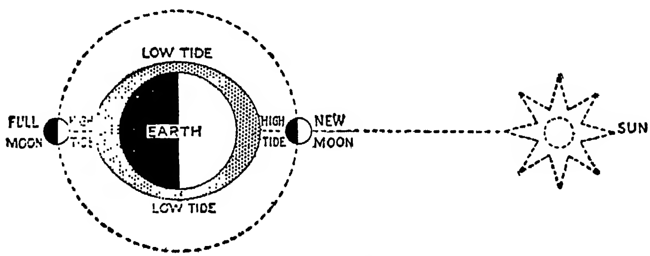
tational pull acting between the particles of the water on that side and the particles of the earth.

We may now return their motions to the earth and the moon. And as the earth turns on its axis, imagine the two water bulges moving round so that one of them is always facing the moon. As each meridian in turn presents itself to the moon's influence, all the places on the earth's surface within that meridian feel the effect of the heaped-up waters. It is high tide at those places. In effect, two enormous waves sweep round the earth every twenty-four hours. The crests of these waves bring high tides; the troughs, low tides. The tide-wave is very, very long, but it is only in the southern hemisphere, where there is a complete girdle of ocean, that it can develop as the theory requires; and you are not to think of it as a high wave, for actually its height is only a matter of a couple of feet or so. In the Pacific and the Southern Oceans the rise and fall of the tides does not measure more than that, and everywhere in the open ocean the tide range is comparatively small.

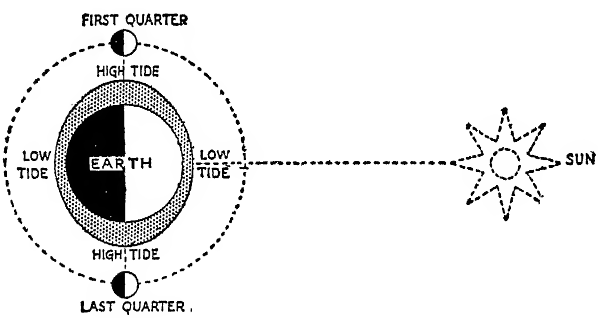
It is only in those seas where land and water meet each other in an irregular and complicated fashion—as in the English Channel and the North Sea, and in the Persian Gulf for example—that there is a big difference in water-level between low and high tides. This is because in such seas, where the water is shallow and there is much interruption from the land, the tide-wave's speed of five hundred miles an hour becomes much diminished by friction. The base of the wave drags along the bottom, so to speak, and the crest of it tends to topple forward on to the land.

The tide-wave starts on its career around the globe in the uninterrupted zone of the Southern Ocean, travelling from east to west; but where the opening occurs between South America and Africa, a secondary wave develops, travelling northwards, and that is rather confusing, because

it is from this secondary wave that the tides of northern Europe are derived, although there is a perfectly good east and west Atlantic wave which is part of the original Southern Ocean tide-wave. But we had better leave the secondary waves alone because we want to think of the major rhythms,



Spring Tides



Neap Tides

the principal oscillations of the seas, rather than the highly complicated subsidiary tide-waves that develop in them.

So far we have arrived only at an understanding of the tides as they are manifested in their daily recurrence and regular progression. If it is high tide at this place or that at noon to-day, it will be high tide at 12.50 to-morrow, and at 1.40 the following day, and at 2.30 the day after, and so on, for the moon crosses the meridian roughly fifty

minutes later each day. And now, what about the spring tides—the more vigorous tides that come with the new and full moon, and the slacker neap tides of the moon's first and third quarters? How are these fortnightly rhythms brought about?

What the moon's attraction does in raising up the water into two tide-waves that follow her around the earth, the sun's attraction does also, but in much less degree. For although the sun is so big—nearly 2,700,000 times the mass of the moon—it is nearly 400 times farther away, and the pull is inversely to the square of the distance. So the moon pulls twice as hard as the sun. What the sun really does is to pull sometimes with the moon, sometimes against her. At new and full moon the sun's tide-wave falls in with the moon's, crest to crest and trough to trough, and the consequent spring tides are three times as powerful as at the times of the moon's quarters. At those times, the crest of the moon-wave falls in with the trough of the sun-wave. This combined wave is obviously lower than the normal lunar-wave, and explains the neap tides. The diagrams should make this quite clear. At the time of the new moon, the sun and the moon being both on the same side of the earth combine to make a big wave, which has its echo in a corresponding big wave on the opposite side. At full moon the sun and the moon are on opposite sides of the earth; here again their efforts are united, and there are extra big waves, but not quite as big as at new moon. And when the sun d moon are at right angles, as at the moon's quarters, the tide-wave is least.

There are, however, some rather remarkable discrepancies in the coincidence of the solar- and lunar-waves, and spring tides fall slightly later than the theory requires. Without going into the astronomical causes, it is as well to point out that the moon's tide is slightly shorter in duration than

the sun's, with the result that the crests of the two waves do not keep absolutely in line. The lunar-wave outruns the solar, and makes the tides a little earlier or a little later than they would otherwise be. When longshoremen speak of the "priming" or "lagging" of the tides, they refer to the lengthening or shortening of the intervals between them, which are due to this cause.

You probably know that the tides are a brake, their friction constantly tending to retard the earth's speed of rotation. Thus our days are getting longer, and in time they will be as long as the period of the moon's revolution round the earth. When that happens, there will be no more moon tides on our seas, and by then the friendly moon born of the earth's side will be a much greater distance away. Longer days, smaller tides, and a dwindling moon—those are the certain prospects for future generations.

Yet vigorous enough are the sea tides now. Swirling, churning, racing up and down channels, tearing between islands, holding a mirror to the sky in some wide estuary, then snatching it away. All over the world the tides are playing strange pranks, making music to quaint rhythms. Think of the Bay of Fundy, of the Severn bore that lifts and lowers the waters at Chepstow fifty feet at springs. Colombo has four tides a day, and so, too, has Southampton, much to the making of its prosperity. In these cases the tides, coming round the sides of an island at the same time, meet in the middle, and the double tides are echoes of the collision. But what about Papiete, in the Society Isles, where they never get a high tide before twelve or after two? Surely that is the queerest of all the tide-waves' pranks.

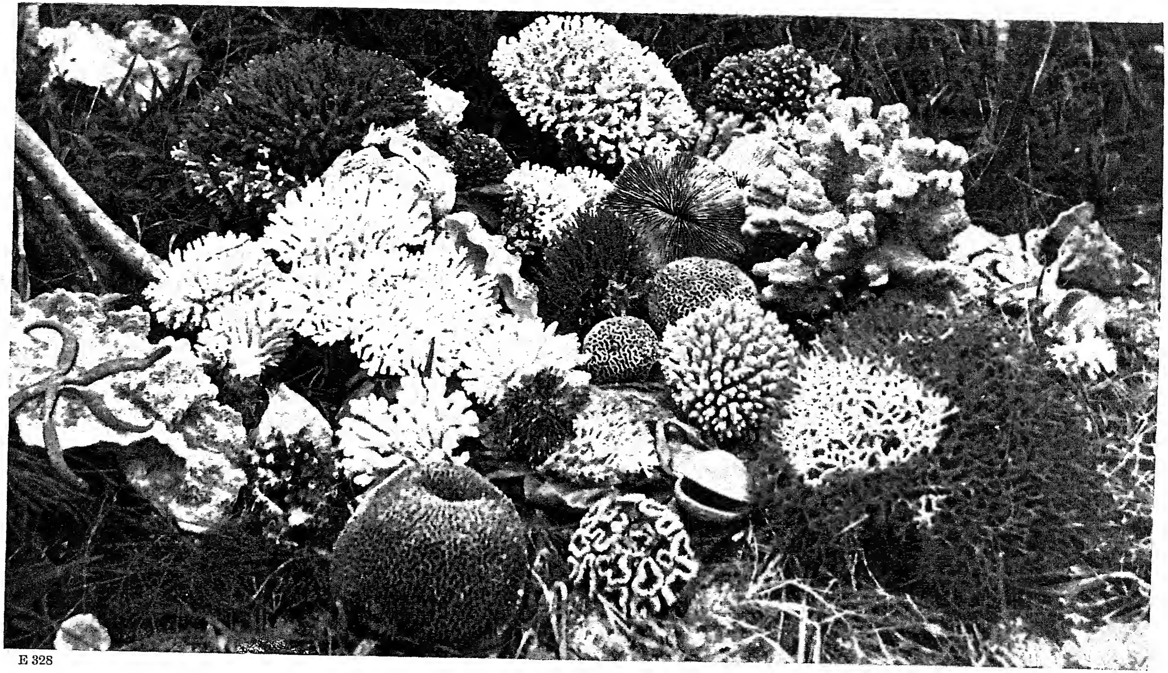
CHAPTER XI

The Strange Story of Coral

We have touched on many mysteries of the sea that oceanography has not yet completely solved. The wonder is, indeed, not that there's a brain-stretching question or two that has to be left unanswered, but that so youthful a science should have developed so far and so fast towards positive knowledge. If you will look at the strange puzzle of the coral reefs for a moment, I think you will agree that the *how* and the *when* offer a most intriguing problem.

Coral is everywhere, remember, an animal of world-wide distribution in the oceans of to-day, and of greater importance as an earth-builder in past ages than it would seem to be at the present time. The coralline limestones of the Tyrol, for instance, are of great geological interest, and there is a pretty complete chain of fossil corals running right the way back to the Silurian Period of the Palæozoic Era—the era of ancient life.

They are beautiful things, these humble builders of the earth of man's delight—more obviously beautiful than diatoms and similar tiny marvels of limestone, the very type and symbol of sea-loveliness. You give a child red coral, and share the child's wonder and delight in the unfolding of the captive sea-anemone, its cousin. Corals are communal sea-anemones, builders of cities of gloriously tinted stone—each colony a million master masons engaged on fairy palaces of complex architecture. Yet they link up



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CORALS FROM THE GREAT BARRIER REEF

They are of amazing colours when first secured but soon bleach to a uniform white

From a photograph by Charles Barrett

Facing page 132.

with the earliest and most rudimentary forms of life, belonging to the *Cœlentera*, the second lowest group of many-celled animals. We saw something of the beauty of the pelagic protozoa in Chapter IV—the one-celled foraminifera that dwell in many-windowed temples of lime, and the one-celled radiolarians with skeletons of glass. Once upon a time—how many million, million years ago none can tell—the protozoa gave rise to animals with many cells. And on the very threshold of life's adventure, at that unimaginable moment when it was ordained that some animals should drift in the sea for ever, that some should swim, that some should crawl upon land, and creeping, flying, walking, should possess it for their heritage—at that pregnant moment in our history the newly-made many-celled animals, the *Metazoa*, turned two ways. One branch became the sponges and never proceeded farther. The other branch developed the cœlentera—jelly-fish and swimming-bells and sea-anemones—types of the simplest invertebrates, yet so mysteriously complex that "simple" is a zoological solecism. For here in the cœlentera is the simple material out of which the magic hand of evolution has fashioned all nobler forms of animal life.

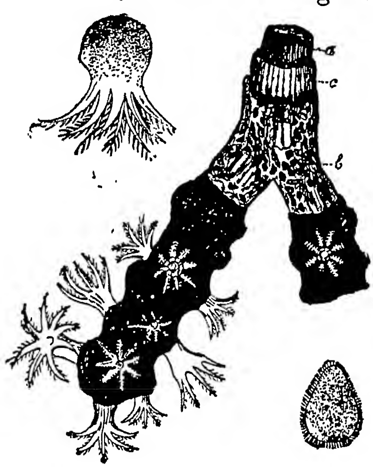
The multiplicity of coral forms is bewildering. The most beautiful forms inhabit warmer, clearer, kindlier waters than those about our own coasts. The "colonial" or reef-building corals—the island builders—provide the very choicest of sea-cameos; marine rhapsodies of form and colour that even the dullest and least responsive find irresistible. As you approach the coral reef close enough for its soft green verdure to stand out against the white strand—a velvet cushion in all the tints of green you can imagine, set about with a moving silver ribbon, now widening, now narrowing, where the surf breaks—as you approach your coral island, the deep azure of the tropic

sea gives place to a paler blue. To look over the boat's side as the water shallows is to gaze into an infinite, amazing thickness of turquoise crystal, through which the white coral sand appears as though illuminated from beneath. Gaudy fishes far beneath you seem swimming in air; occasional sponges of brilliant red, here and there on the glowing bottom, look like mounds of burning fire seen through some magic glass, so intense is the colour, so marvellous the transparency.

But wait! As the water shoals the reef comes up, gradually, steadily—ten fathoms, five fathoms—and you gaze upon a new world—unsuspected, unbelievable. There is the fairy-land—crags, castles, pinnacles, and palaces wrought as nothing else on earth was, ever wrought; seeming carved in ivory, jet, jade, and jasper, cornelian, sapphire—every precious stone, in a mad intricacy of form but exquisite craftsmanship. There is the colourist's paradise—colour come into its own at last. Colour! There is no end, no beginning, to the scope of this palette. It is like looking upon Nature's paint-box, left unlocked and under a panel of crystal. Here are giant elk-horn corals, brown and purple; great domes and cupolas of vivid orange; huge feathery gorgonias—fans of royal purple and softest yellow. There are corals of every conceivable shade of green, blue, red, lilac. The anemones hold forth a million delicate fingers of a thousand delicate tints, swaying, waving, dancing like flowers moving about an impossible garden.

The fish inhabiting this exquisite world are fitly clad. In and out of the gardens, through the fretted palaces, goes the gay carnival, splendid in sheen of silk and satin, in beaten gold and burnished silver, lustre of copper and bronze, and the smoky softness of lead; in gay riotous flashes of primary colours and in the pastel vestments of the rainbow. And just as the colour schemes of the myriad fish

seem without end and endlessly changing, so with their shapes and outlines. Fish grotesque and fish preposterous, circle and maze with the fish orthodox in fin and form. And as you gaze upon the wonderland and try to fix attention on a single inmate, behold, you are undone! Your red beauty or your green, or your Jacob among fishes, changes his coat before your very eyes, and as though in mockery puts on an entirely new colour or plays pranks with the spectrum in a way to make you doubt your sight and sanity. Even the clumsy octopus plays chameleon as he glides down the gorgeous groves.



Red Coral magnified, showing Polyps projecting at intervals

The colours of the coral reef are its living mantle. Divest it of this and the skeleton is usually white, like the sandy shore composed of its fragments. The true reef-building corals, the madrepores, have a solid skeleton, but there are generally associated with them the millepores, in which the common skeleton is perforated with minute canals connecting the millions of individual polyps in the colony. The millepores are exceedingly interesting, because of the division of labour that appears to exist in the colony, which is shared by two distinct kinds of polyps of different functions. One sort is a polyp with a mouth and stomach. These are the masons of the community, the skeleton builders. To their mouths comes food at second-hand, brought thither, ready-prepared, by smaller warrior polyps that have no

need for food themselves, since they are mouthless. But they are admirably armed, none the less, for their long tentacles are covered with poison darts to paralyse the microscopic animals with which the mason-polyps like to be fed. It is because of these poison cells, which sting like nettles, that the millepores are commonly called stinging corals. How, you may ask, can a mouthless animal grow? Well, the process is too deep for explanation here; but you must understand that the nourishment and cell-increase of the mouthless polyps takes place through the canals in the common skeleton they share with their feeding brethren.

All the polyps have odd methods of reproduction, but that of the millepore is surely the oddest. For you are to understand that for the building of new colonies the millepore produces not eggs, nor infant corals like themselves, not anemones even—but members of another branch of cœlentera. They give birth to tiny jelly-fish, with power to swim, and these in their turn produce eggs from which arise the larvæ that eventually anchor themselves to stones and grow into the great massed colonies of millepore coral. Here again we are in touch with the unperceived but insistent natural rhythms—one of the most subtle and most mysterious of all the wonderful rhythms around us, that known as alternation of generations. Here in the corals you see the strange waves of sexual and asexual reproduction that are, indeed, one of the most conspicuous characteristics of the primitive cœlentera.

But whether madrepore or millepore or any other type of massed or "colonial" coral, the method of increase, once the colony is established, is vegetative. The polyps multiply in the colony much as plants grow by the development of bud after bud for the formation of shoot and branch. When a free-swimming "larva"—a dot of jelly covered with microscopic hairs—finds a suitable resting-place, it

just sits down to grow. It gradually assumes the typical anemone form, broadens at the base, develops a mouth and a pleasantly simple interior to serve as stomach. Around the mouth the filamentous tentacles emerge, armed with poison cells, and with these waving hands the animal catches its dinner. Whether it deliberately seeks its prey, picking and choosing the tit-bits, or whether all is grist that comes within the range of its tentacles, I cannot tell you. And whether the lime comes out of its food or out of the water circulating through its organs I cannot tell you. All that is clear is that lime taken *somehow* from the sea presently comes to form a hard crust, a case or " skeleton " ever thickening around the polyp. Then a bud forms at the side of this solitary coral, becoming in time a second individual, lime-encrusted like the first, then another bud higher up, then another, and next, new buds on the new branches, and so *ad infinitum*, new polyps always growing out of old polyps, coral massing upon coral. It is said that Samoa gains a thousand tons of new coral rock in a single year!

The island builders are fastidious. You are to know that your atoll—an island in the form of a ring—must be sought in seas of crystal clarity, of genial warmth. You needn't look for it off the west coasts of Africa or America, where the cold sides of the water-whirls flow before they turn equator-wards again, and great rivers bring down their thievings. But on the east coast of America [1] and in the Indian Ocean—in all clear seas where the temperature is never below 68° F., there you may find a coral isle. The Central Pacific is the happiest hunting-ground, where atolls occur in hundreds. It may be a reef-island, one of a long chain, or an isolated atoll—a tiny dot in a limitless sea, a dot less than a mile across, or a richly-clad island

[1] Reef-building corals reach higher latitudes here than anywhere else owing to the Gulf Stre   influence.

as large as an English county and as lovely. The reef may be of enormous length, like the Great Barrier Reef off the coast of Queensland, more than 1300 miles long and separated from the mainland by a strait varying from twenty to seventy miles wide. But whether barrier reef, separated from land by a wide channel; or fringing reef, which is virtually joined to the mainland and has no intermediate channel; or atoll, which is a low isolated reef, ring-shaped or horseshoe-shaped, enclosing a lagoon or sea-lake, the method of growth is always the same.

Most appropriately it was a poet who first drew attention to the astonishing story of coral reefs. He was Adelbert von Chamisso, a German poet of the early nineteenth century, who was also a writer on natural history. In 1815 this German poet-scientist sailed into the South Seas and so came up with coral islands. He brought back the first clear account of their formation, showing how the polyps cease to grow when the reef has reached the sea-surface, and how the dead coral, exposed at low tide, becomes broken up by the waves and cast up in mounds piled upon the living reef so that the dry land appears. Well, unless he made it clearer than that, he wasn't very helpful. It seems necessary to go a little deeper for a start.

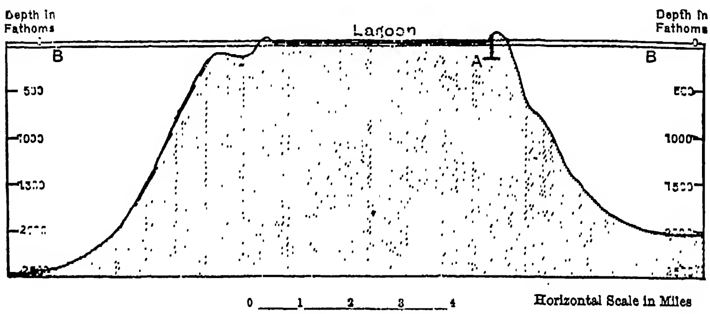
And here begins the great mystery. Because the deeper we go, literally, with a sounding line, the thing becomes curiouser and curiouser. Coral reefs rise from very deep water—thousands of fathoms deep, in fact. Yet the polyps do not build below thirty fathoms deep, and are most active in still shallower water. That is one of their chief peculiarities. The reef-builders are essentially shallow-water animals. Many of them are associated with minute algæ, in a peculiar state of intimate union called symbiosis, and it is argued by some authorities that this circumstance provides the expl ation of their shallow-water habits.

The plants must have light for their nutrition and below the thirty-fathom level the light is insufficient. But every reef must have a foundation, and on the nature and origin of the foundation the great puzzle revolves.

Take the fringing reef, for an easy start, and see how it grows. We know that on the rocks of any suitable coast the free-swimming larvæ fasten themselves and grow and increase in the manner already described. They start somewhere near the thirty-fathom level and grow upwards, but when they reach the surface they cease to grow higher, for they cannot live exposed to air. Consequently, subsequent growth must be outwards, and since there is no growth *below* thirty fathoms the slope of the coral bank becomes steeper and steeper, more and more precipitous, however gradually the original beach may have shelved into the sea. Very well; the topmost layer, exposed at low tide, dies, and the waves continually pounding upon the reef break off great boulders of coral, some of which are washed shorewards, to form what is called a "boulder zone" on the rim of the reef; others are tumbled down the steep face of the reef and so provide a new footing farther seawards, on which the polyps can start anew. Besides the waves there are other disintegrating influences. Corals have many enemies, boring animals of different kinds working to undermine huge chunks of reef.

Thus the reef grows always seawards. For one thing, the polyps exposed to the open ocean have a better food supply, the inner members of the colony having to put up with stale provisions. These succumb ultimately to slow starvation and suffocation from the mud and sand of the crumbling debris of the boulder zone, which, of course, follows the reef seaward. Behind the rampart-like mound of the boulder zone the lagoon is presently formed. The sea swirls through breaches in the rampart, carrying away

broken corals, dissolving the lime again with the help of carbonic acid from the decaying seaweeds, and ever deepening and widening the lagoon channel between the reef and the land. When this stage is reached the fringing reef has become a barrier reef. Meanwhile the outer rampart becomes more and more land-like, the interstices of the boulders are filled with sand of coral and shells and lime-encrusted seaweeds and become cemented in hard

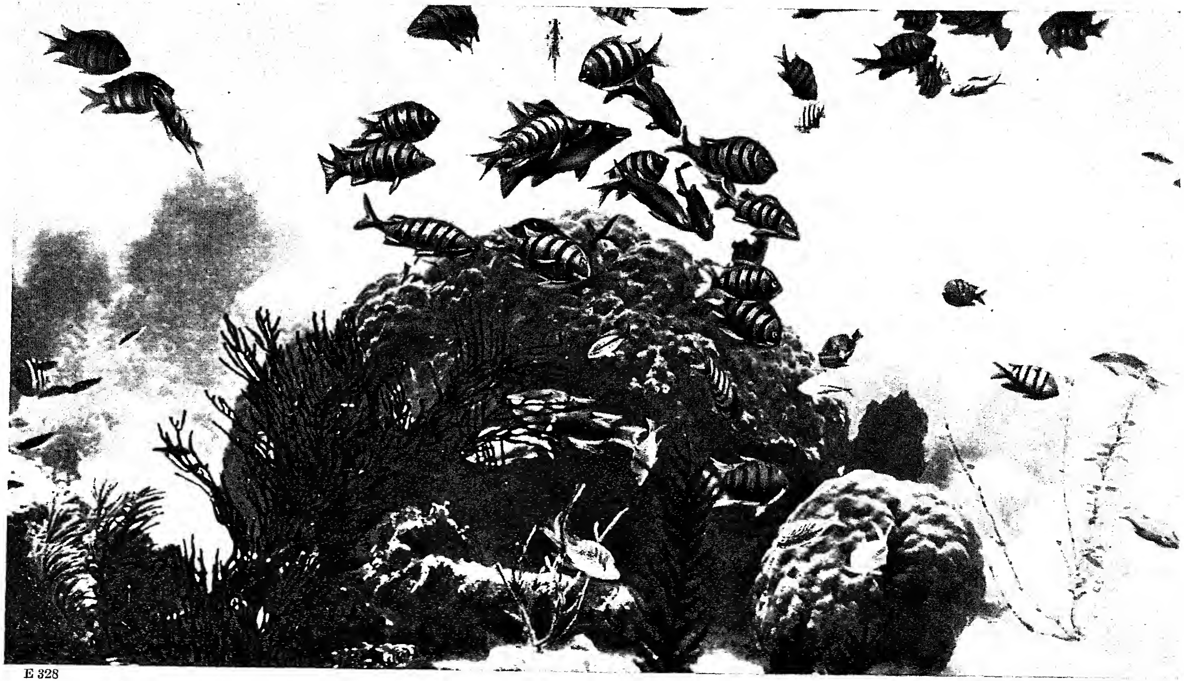


Section across the Atoll of Funafuti

A, Coral reef proved by bore-hole. B, Maximum depth of life of reef-building corals (30 fathoms). Their usual limit in depth is about 15 fathoms. Outline from a survey by Captain Field.

rock-like masses. All of which is reasonable and intelligible.

But now take the case of the atoll, hundreds of miles from land, rising out of ocean thousands of fathoms deep. How did this lonely ring of coral—this circlet gemmed with islets enclosing a sea-lake—come to be upraised? The method of growth was doubtless the same as, or similar to, that of the fringing reef just described, but the foundation obviously requires a different explanation. Darwin, you remember, came under the fascination of this problem during the voyage of the *Beagle* in 1842. His theory was picturesquely stated by someone who called the atolls "garl ds laid by the hand of Nature on the tombs of



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TRAFFIC AT THE BOTTOM OF THE SEA

Shoals of exotic tropical fish meet at a large head of coral

Photographed by J. E. Williamson, from a specially built studio under the waters surrounding the Bahama Islands

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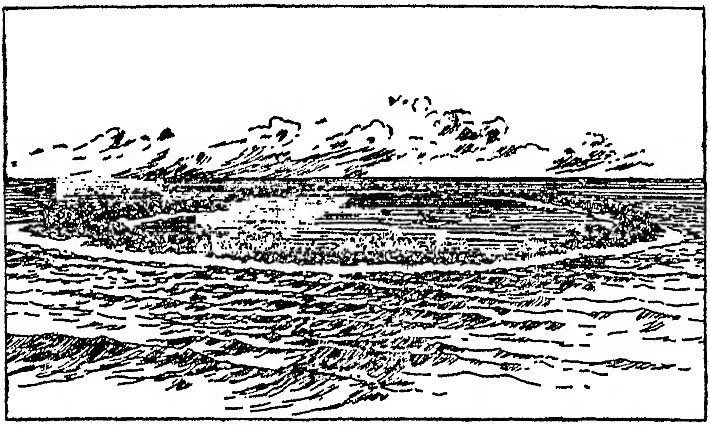
sunken islands ". Darwin supposed that all atolls originally started as fringing reefs on the shores of islands. For since the coral reef could not lay its foundations in water deeper than thirty fathoms, only where established land-masses emerged from the sea could the necessary condition of depth be fulfilled. And he argued that if the foundations were submerged mountain summits, just below the surface (as Chamisso had supposed) it was inconceivable that such



An Atoll

mountains, spread over thousands and thousands of square miles of ocean, could have remained everywhere within a few feet of the same level.

The whole explanation, Darwin thought, was this. Each atoll was once an island, on whose shores corals started a fringing reef. The island was sinking, but the upward growth of the reef kept pace with the subsidence. In time, the fringing reef grew to a barrier reef, a shallow inner channel, greater or smaller as might be, becoming formed (as we have seen) between the reef and the island proper. In time again, the summit of the island would sink beneath

the waves; but the corals would still maintain the reef, for they would be building ever upwards on a vast platform of their dead skeletons even when the earthy foundations of the original reef were thousands of fathoms under water. There was nothing intrinsically improbable in this theory. Darwin, of course, knew the chances of subsidence as a geological factor; knew, too, that most coral islands occur along a gigantic " fault ", a region of instability and volcanic outburst. To us, looking at the map, Pacific Islands appear to be sprinkled over the ocean in an extraordinarily promiscuous and haphazard fashion. But the geographer knows better. He links them up in definite chains, which he calls " festoons ".

The principles of isostatic balance now come into the problem. We know that if a volcanic outburst raises a mountain on the sea-floor, the chances are definitely in favour if its gradual subsidence, owing to its immense weight. To that extent, therefore, modern knowledge is in favour of Darwin's subsidence theory and the " garlands on the tombs of departed islands " are not a poetic extravagance. But as knowledge of atolls increased with systematic investigation, it was gradually borne in upon the investigators that Darwin's theory couldn't completely fit the case—or rather, all the cases.

In the first place, it was shown that while the foundations of some atolls with very deep lagoons might be sinking, there were others in which there was evidence of emergence. Their lagoons, instead of getting deeper, as required by Darwin's theory, were becoming filled up; while the shaping of the cliffs and bays of some reefs further supported the belief that they were becoming upraised. And the more they thought it over, scientists grew the more reluctant to accept the likelihood of a vast general submergence on the scale put forward by Darwin. They found no geolo-

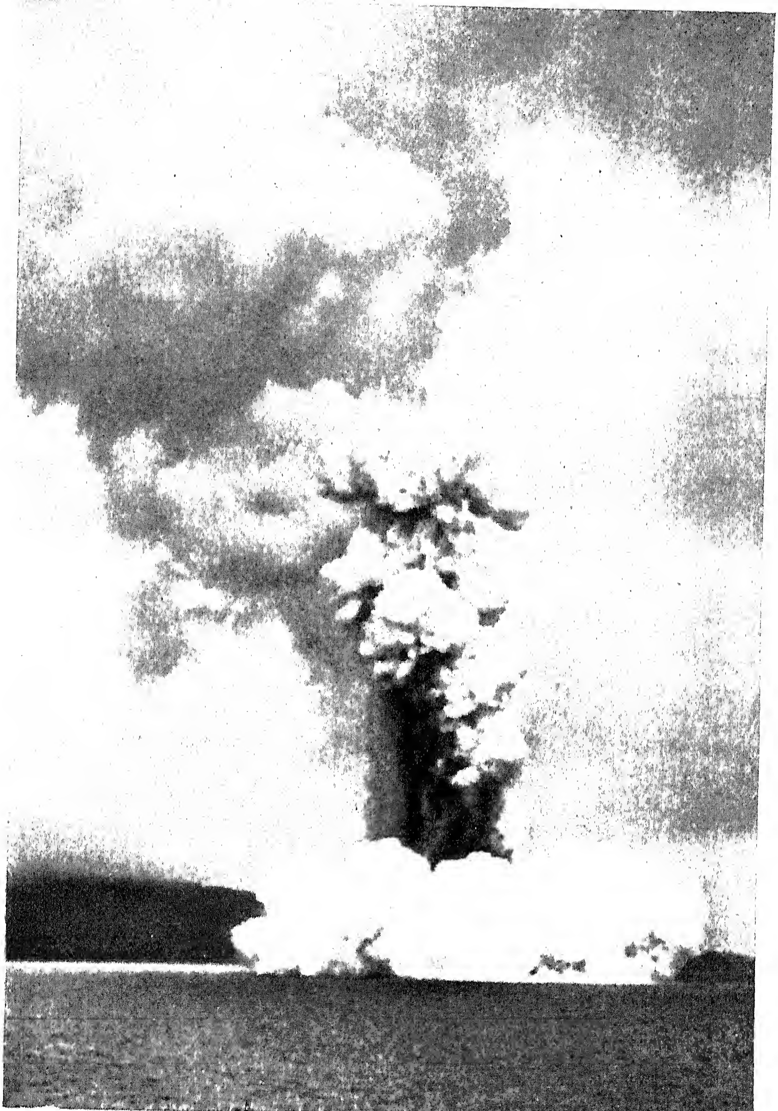
gical evidence in support of it; and so far from the slow submergence required by the theory, many coral reefs appeared to be of very recent origin.

So there they were stuck, until the late Sir John Murray advanced an alternative theory that was almost the exact opposite of Darwin's. He argued that the reefs, instead of being commenced on the shores of lands that had subsequently sunk, probably had their beginnings on submarine platforms raised by volcanic action. Every coral atoll, in short, was laid down upon a mountain-top. And if it seems rather a startling notion that the tropic seas could have been, within recent geological times, the scene of volcanoes enough to provide the sites of so many reefs, remember that stranger things have happened. Remember the "domes" we encountered on our journey over the Atlantic floor—and hear the history of Falcon Island, a dot in the Micronesian Festoon, near the Friendly Isles. A volcano pushed it there from out of the depths in 1883—a peak 250 feet high; but it soon decided that existence wasn't worth while and disappeared beneath the waves, to remain as a shoal for many years. That ought to be the end of its history; a jack-in-the-box entry on the Pacific world, and a disappearance equally sudden ought to be enough for any volcanic island. But Falcon Island, though it may lack the charm of permanence, can't be denied the merit of persistence. Up it came again, a year or two ago, and this last eruption (1927) even raised it higher than before. But whether or no it still qualifies for a place on the map is more than I can say. Falcon Island is by no means an isolated example of a temporary island, though perhaps it is the most sensational. There is a "disappearing island" off Iceland, and the island of Anak Krakatao, 170 feet high, suddenly vanished, while this was being written.

Sir John Murray presupposed the raising up of the land

to form suitable platforms, within the thirty-fathom depth, upon which the corals could grow upwards. He wasn't so foolish as to suggest that every atoll was built upon a mountain summit that a marvellous coincidence had raised to within thirty fathoms of the surface! Some of the volcanic cones would have been thrown high above the sea; but these, being composed of pumice and soft volcanic ash, would very quickly succumb to the denuding influences of wind and waves. Even when nothing remained above sea-level the abrading processes would be continued by the scour of tides and currents, but these would cease within the range of the reef-builders. On such a convenient and hardened platform they would soon get to work, but not quite in the way required by Darwin's theory. For the corals would develop not along or around a fringe of shore, but over the whole of the submerged platform. Thus they would not reach the surface in the form of a ring but in a plate-like mass over the whole area they built over. The typical atoll form, however, would necessarily follow from the gradual starvation and decay of the inner corals, just as in the case of the fringing reef.

Nor is it necessary, according to this theory, that the volcanoes should all be erupted to such a height that their cones came either above water or within thirty fathoms of the surface. Many of them would have their summits far below that depth; but sooner or later they would become built up to the shallow-water levels required by the corals. For you must know that in these warm latitudes a submarine mound becomes very quickly covered with the remains of the teeming organisms of the waters, and as the deposit grows in depth so the mound grows in height. Deep-sea corals, remains of animals and plants of many kinds, and the ceaseless rain of pelagic foraminifera between them raise up the mound out of all proportion



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THE ISLAND OF FIRE

A photograph of Krakatoa, two-thirds of which were blown to pieces in 1883 with the loss of 35,000 lives on neighbouring islands. Over 3000 eruptions, some reaching a height of 2000 feet, were recorded within twenty-four hours recently.

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to the upgrowth of the surrounding area of the sea-floor.

Thus, on the margin of the jewel-like atolls, a battle-royal has raged for years. Many very distinguished oceanographers threw in their weight for Murray's theory, others defended Darwin's. Borings on a typical reef revealed a depth of more than a thousand feet of coral rock, proving that subsidence must have occurred in the case of that reef, and to that extent bearing out Darwin's theory. But science is not really satisfied with either hypothesis. There are awkward facts and puzzling conditions connected with the depth of the lagoons, the shapes of the atoll rings, the configuration of the neighbouring coasts, and suchlike matters, too complicated to go into now—that make it improbable that any general theory can ever solve the whole mystery. But observe for a moment how serenely the gaze of science sweeps past the boundaries of our narrower horizon. For us, the wonderland of our coral isle may be a day's delight—an excursion to touch imagination, give zest to wisdom and appetite to fancy. Science does not disdain the things that poetry lays hold of—the embroideries that we admire—but its wider, deeper vision looks past the morning and the evening that shut in our days, so that it sees the laws of nature unhampered by boundaries of time. The busy polyps of to-day are building always on the ruins of yesterday. That much has been clear since the days of the poet Chamisso. May not the yesterday of the foundation of the coral reefs be a more distant one than science has hitherto supposed?

Islands—and icebergs! Is there a connexion? This is the question those seeking to unravel the great mystery are now pondering. Turn your mind for a moment to the Pleistocene Period of earth's history—the last division of the Kainozoic Era; interpreting the geological terms literally as the " most recent " period of the era of " modern life ".

It takes us back no more than a quarter of a million years. It was a period of great unrest. It was the Ice Age, fraught with strange adventures for the men and the beasts of those days. Nearly all the modern forms of life—animals and plants—were in existence then, and a very pretty dance they seem to have had in dodging the climatic oscillations of their times! However they were caused, these oscillations resulted in the formation of vast ice-sheets over what are now the temperate regions of the earth. A theory put forward by an American scientist, Professor Daly of Harvard, definitely associates the conditions necessary for the shallow-water platforms on which corals grow with the conditions of the last Ice Age.[1]

Daly's "Glacial Control" theory, as it is called, is now receiving a good deal of attention. Daly doesn't believe that the reef foundations are moving either up or down. He thinks they have long been stationary, and that they are the remains of volcanic eminences of pre-Pleistocene times. But during the Ice Age an incalculable quantity of water was locked up in the forms of ice-sheets and glaciers, which spread out over much of what are now temperate regions. In polar regions the ice-cap must have been thousands of feet in thickness. It would be very interesting if we could know what was the result of the displacement of this enormous volume of water, drawn from the tropics and loaded upon the Poles. How did the lithosphere buckle and shift its shape under the changed load?

But do you begin to sense the significance of Daly's picturesque theory? Take all the rain and snow and freeze it into solid ice so that it can't go back to the sea, and clearly, the result is less sea. The thicker the ice-cap, the wider the glaciers, the lower the ocean becomes in the tropics. Also,

[1] There were several frigid periods in the Ice Age, perhaps six in all—each followed by periods of more moderate, but inconstant, climate.

as the ice-caps increased, their gravitational attraction may well have drawn up the water towards them, just as the great land-masses do. And so, according to Daly, the sea-level was probably lowered by 200 or 250 feet. The waters even of the tropics must have been chilled during the Ice Age; there is evidence of ice as far south as the Azores; and consequently existing coral reefs would be killed, and the island shores they protected would be at the mercy of the waves. So they became abraded, washed down, step by step, becoming "benched", as the seas were lowered, until at last (being mostly mud and volcanic and coral debris) they were reduced to platforms just awash.

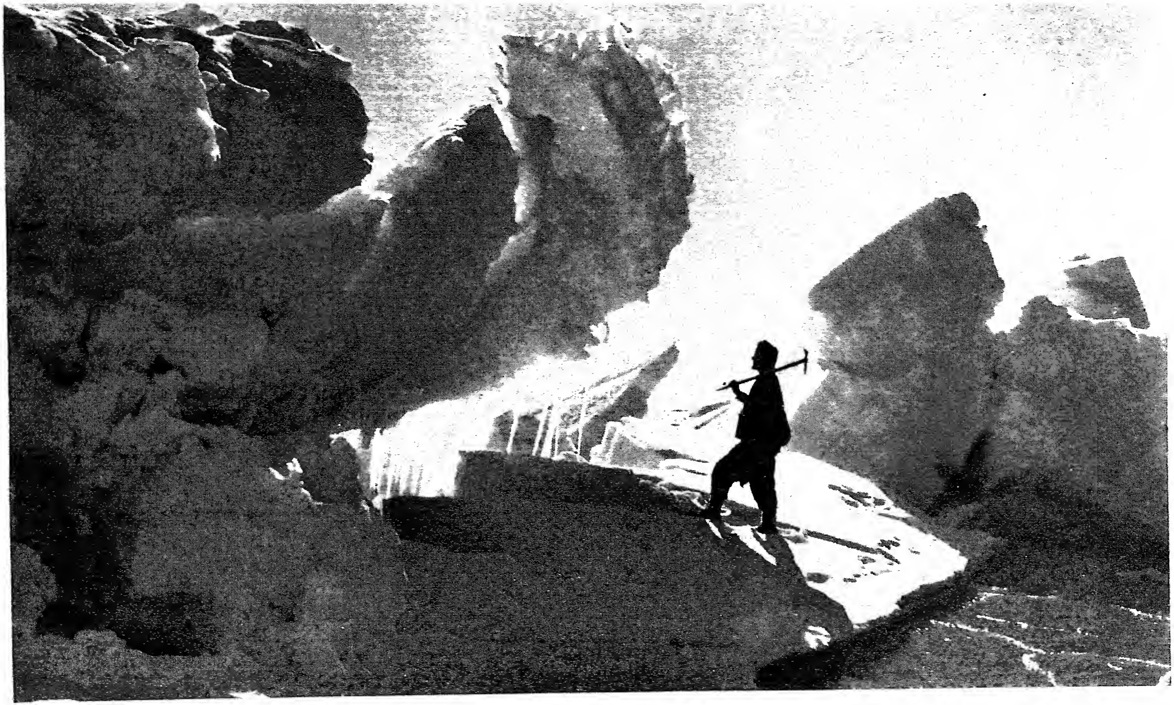
Presently the frigid conditions gave place to better times. The glaciers and the ice-sheets thawed and the sea came into its own again. Slowly, of course; but while its level was rising it was getting warmer again, and the corals and coral larvæ, long confined to the equatorial belt, or to very warm and sheltered inlets, would drift more widely about the tropic seas once more. They found the old islands of their fringing and barrier reefs no longer in existence, but there remained of them the debased platforms, ten or twenty fathoms down, and on the edges of these the polyps could start anew. Century after century the waters continued to rise again, but the upward growth of the reefs on the rims of the submarine platforms would be able to keep pace with the increasing depth of water. At last the corals reached the surface, new boulder zones were formed, new lagoons hollowed out, and the atolls of our day came into existence where once had been the heights of pre-glacial islands. Well, that's Professor Daly's theory, stated in its main outline. It finds some support from science, and makes matter for debate. And you must agree that the link by which ice may have made coral reefs in tropic seas is one to touch the imagination.

CHAPTER XII

The Frozen Seas

In the last chapter we came in touch, rather unexpectedly, with the ice-cap of the Pleistocene System. Fortunately for us, there is a good deal less ice in the world now than there was in those days, a quarter of a million years ago, more or less. None the less, I fancy that most of us have rather hazy ideas of how big the modern ice-areas really are. Now, the Arctic Circle and the Antarctic Circle each embraces an area of five and a half million square miles—a territory a good deal larger than Russia in Europe and Australia combined. If you can bring yourself to picture it in that way, what are vaguely known as the polar regions may take on more vivid proportions.

But although, geographically, the Arctic and Antarctic regions are the same in area, they are physically very different. The great ice-field of the Arctic Ocean becomes broken up in summer and wide lanes and channels are formed between the uncountable floating islands of ice. In the Antarctic on the other hand, the ice-field stretches far northward beyond the limits of the Antarctic Circle. The Arctic regions are relatively warm, and the weather relatively calm. There you have a great ocean, roughly 1500 fathoms deep, almost encompassed by a ring of land not much above the Arctic Circle. This ocean is comparatively warm—(if you can bring your mind to think of seas as warm which are only just above the freezing-point of



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WAVE-TOSSED PACK-ICE

Pressure ridges in the Ross Sea

From a photograph by F. Debenham, by courtesy of The Scott Polar Research Institute

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fresh water)—and it has a very important influence on the climate of the north polar regions. The pack-ice formed in winter about the southern parts of the Arctic Ocean is never very thick, not more than seven or eight feet as a rule—though there are wide areas where the ice is as much as fifty feet—and because the ocean is nearly land-locked, this pack-ice cannot escape in enormous quantities when it breaks up in summer, but mostly melts actually within the Arctic Ocean. And that in itself helps to make the water warmer, the explanation of the paradox being that when sea-water freezes most of the salt becomes "squeezed out", and the melting pack-ice—(like icebergs, which are entirely fresh water originating on land)—releases water which is much less salt than the surrounding sea. That ought to make the sea colder, one would think; but the *less* salt the water is, the more readily it absorbs heat, consequently the ice-water warms up more quickly during the short Arctic summer than the normal sea-water.

One result is that the North Pole is some twenty degrees warmer in summer than the South Pole. Doubtless you know what a vast difference there is in the life inhabiting the Arctic and Antarctic Circles. In the north, where the great glaciers of Greenland and Spitzbergen grind their way down to the sea through the fiords, there are in summer great stretches of coastland, often a good deal broader in extent than the breadth of the southern English counties, where, for a short season, flowering plants flourish in profusion and the air is filled with the hum of insects. There is nothing of the life of the Arctic Islands to be found on the frozen continent of the south. Except for the bird-life and sea-life of its outer fringes, the world of Antarctica is an utterly dead world. This great continent is well called the "refrigerator of the world". We think of it, quite properly, as the most elevated of all the continents—a

sombre, sinister table-land, mostly over 8000 feet high, beset by peaks rising more than 15,000 feet. But we do not always grasp the significance of the ice-cap that covers it, and the influences it may have for future generations of men.

Though the North Pole has its ice-cap it is an insignificant affair compared with that of the south. And neither has always been there. Both in the Arctic and Antarctic, temperate plants once flourished luxuriantly. Indeed, the fossil corals of the far north betoken a period when the waters were at least of sub-tropical warmth. Greenland and Spitzbergen have extensive coal-fields, and Antarctica holds vast reserves of coal that may well prove to be the last of our failing fuel resources. And though, as yet, there is no definite answer to the question whether we shall ever be able to tap these coal reserves, there are at least indications that the gigantic southern ice-cap is waning. It is said that the ice is lessening fairly rapidly; it is thought to be now 700 or 800 feet thinner than it was a few thousand years ago, even, and geologists and climatologists incline to the belief that the waning of the ice will proceed more quickly during the next few thousand years.

Now, if these indications are confirmed—and there is every reason to suppose they will be—the phenomenon of the dwindling ice-cap adds a new chapter to our story of the sea. As the ice melts the sea-level must rise. Science states that a diminution of 35 feet in the thickness of the Antarctic ice-cap raises the sea-level, all around the world, by one foot. The sea-level is therefore some 25 feet higher now than it was before the time of the *known* reduction of the ice-cap. Have a look at the ice-cap for a moment. It covers an area of 5,000,000 square miles—a million and a quarter square miles greater than the area of Europe; and the thickness of the ice—now c we possibly tell how thick it is?

We can't measure the thickness of the ice-cap directly, it is true. But though they have not been able to bore through it, scientists have been able to arrive at a pretty shrewd estimate of its thickness by the aid of our old friend isostatic balance. They observed as a peculiarity of the Antarctic continent that the platform of the Continental Shelf lay at a quite exceptional depth, at 200 fathoms in fact, instead of 100 fathoms. They supposed that the great weight of the ice had caused the continent to sink down to the extent of the extra 100 fathoms. Well, if the whole continent has been forced down 600 feet, the submarine rocks on which it rests must also have been forced down 600 feet. It was estimated that as rock is three times as heavy as water, the weight of at least three times the thickness of rock depressed must have been required to depress it. And the answer works out: foundation depressed 600 feet, ice-cap depressing it, 1800 feet. If this colossal ice-cap ever melts entirely—as it may—within the next few thousand years, it may bring relief to mankind's fuel-starvation. The chances are, of course, that by then he will have appeased his appetite in other ways.[1] But it will undoubtedly have a queer effect on his harbours and sea-communications. The sea will be everywhere fifty feet higher, and the quays and ports and coasts of our history will have become strange hunting-grounds for the archæologists of that generation.

Icebergs—grim castaways from the uttermost fastnesses of the frozen seas—are fresh-water ice, formed on land. To these detached fragments of the polar ice-caps we may return in a minute. Sea ice does not produce icebergs, but it exhibits many different forms, all interesting, some of

[1] The production of carbon compounds from carbonic acid recovered from the atmosphere, seems to offer the most hopeful prospect of escape from the exhaustion of the carboniferous remains of past ages.

them of wonderful beauty. Polar navigators recognize different kinds of ice by their appearance. There is first of all the " slush ", which is composed of the unamalgamated ice-crystals which always form on the surface whenever the temperature of the water is at 29°,—3° F. below the freezing-point of fresh water. The slush is several inches in thickness, black in colour, and more or less translucent. It is quite unlike fresh-water ice, for instead of being hard and brittle it has a strange sticky consistency, like thick glue. Objects sink through it, as through rather soft asphalt, and seals can push their noses through when they come up for a breather. This slush or " black ice " is often more difficult to navigate than the harder " white ice " into which it presently solidifies; for the slush, heaving to the motions of the waves like some stupendous overflowing of tar or treacle, greatly impedes a ship's passage.

As the frost increases, the black slush becomes the sparkling white ice typical of polar seas. The first crisp, hard ice of the autumn is known to seamen as bay ice, because it forms first in bays and sheltered inlets. Whaling ships force their way through it quite easily, long splits opening ahead of them with a grinding, crackling noise. Next in the wonderful pageant of the frozen seas comes the strange phenomenon of the " pancake " ice. Under the influence of disturbing causes such as surface currents, winds, and tides, the thin ice-crust splits into fragments of regular hexagonal pattern. " The crust divides into thousands of hexagonal discs from about one inch to several feet in diameter, the diameter increasing with the thickness of the bay ice. In between the discs, the shiny black lines of water broaden into wide lanes, and the surface of the sea is like a patchwork quilt. Now, some slight disturbance occurs, a little wind or tide, which causes the surface waters to come together again, the more or less hexagonal ice-discs

hustle together, their delicate sides and corners are crushed and broken, and are curled up by the pressure. Thus they become subangular discs each with a flat interior and a bruised turned-up edge, like a pancake. Again the motion of the surface of the water, due as often as not to tide, separates these discs, again they are hustled together and bruised and get their edges still more turned up. This goes on continually, and meanwhile the discs are thickening and solidifying with the continued low temperature."[1]

The amalgamated pancakes presently freeze into the gigantic sheets of ice stretching far away beyond the range of eyesight, it may be for hundreds of miles. These are the floes, or " fields ", through which the stout ships of polar waters have often to pound a passage. Full speed ahead goes the ship, crash against the ice, with a thundering blow that resounds far and wide. Men brace themselves for the shock that nearly throws them off their feet. The good ship staggers and trembles; then astern again, to get new way for the next charge ahead—all her weight and all her engine power driven full-tilt against the stubborn floe. Perhaps a third attack, or a fourth, before the ice gives way and yields a narrow lane of black water, strewn with ice islands that have to be pushed and nosed, with the ship's bluff bows, now this way, now that, to yield her passage.

These gigantic ice-sheets formed about the edges of the polar seas vary much in thickness. The Arctic floes are usually much thinner than those in the south; probably only five or six feet for the ice of a single winter, though where it fails to melt in the ensuing summer, it is of course much thicker. You may meet sea ice fifty feet thick as you approach the North Pole—floe frozen on floe, year after year. Sir John Ross's ship the *Victory* was locked

[1] Dr. William S. Bruce, *Polar Exploration.*

in the ice in the Gulf of Boothia in about north latitude 70° for three winters in succession. In the summer following the first winter (that of 1829–1830) the *Victory* was able to move no more than half a dozen miles from her winter quarters. On 28th August, 1831, Ross found his ship momentarily free, but exactly a month later he was again imprisoned, and condemned to spend a third winter within walking distance of the inlet in which he had been ice-bound two years before. It was then that he decided that the *Victory* must be abandoned and an effort made to drag the boats, mounted on sledges, over the ice to a point where there seemed reasonable hope of finding open water the following summer. That dreadful journey by Ross's scurvy-stricken men and the hardships of their fourth winter, make one of the most heroic chapters in the story of polar endeavour.

Slush—pancake—floe—and after that, in order of formation, the most dreaded of all sea ice, the fierce, unruly pack. Pack-ice is the product of the wild hurricanes of the polar seas. The monstrous billows arising from these storms strain and bend and twist the ice-floe above them, be it so thick and solid that no human device could ever split or crack it, until at last it can resist no longer and breaks up into huge islands several miles across. Then these islands break again, the miles are rent into acres, and the sea, released then from its bondage, flings the giant remnants of its fetters against each other; breaking them into thousands of pieces, piling them in heaps that freeze at once, only again to be shattered and tossed, hurled upon each other d frozen anew in fields and terraces of an indescribable confusion.

Thus the turmoil in the outer parts of the ice-field, where the floes are most easily shattered by the violence of tempest after tempest heralding the approach of winter, sets up

strains that are felt far back in the solid floes, many miles away from the scenes of the titanic contests between waves and ice. The huge jumbled masses of the pack are forced against the rearward floes, driving on and on before wind and sea, until ice-sheets the size of English counties crash together, their edges curling over and over in long irregular ridges and chains like miniature mountain ranges—the " pressure-ridges " and " hummocks " of polar topography. ' The shrieking, screaming, and groaning of the immense masses of ice as they are forced together is truly horrible," wrote a famous observer,[1] and Sir John Ross vividly describes the fury and confusion of the pack-ice in a storm off the coast of Boothia. " Let my readers remember that ice is stone, a floating rock in the stream, a promontory or an island when aground, not less solid than if it were a land of granite. Then let them imagine, if they can, these mountains of crystal hurled through a narrow strait by a rapid tide; meeting as mountains in motion would meet, with the noise of thunder, till losing their former equilibrium, they fall over headlong, lifting the sea around in breakers and whirling it in eddies; while the flatter fields of ice forced against these masses or against the rocks by the wind and the stream, rise out of the sea until they fall back upon themselves, adding to the indescribable commotion and noise which attend these occurrences."

Than the charging, crashing pack-ice, no phenomenon of ocean is so stupendous or so deadly. A ship caught in the outer pack has small chance of surviving the turmoil. And it must be remembered that in spring, when the floes are " rotting "—that is, beginning to melt with the rising temperature of the water, and again in autumn, when the floes are forming anew, and new ice and old combine once

[1] Dr. Richard Smith, hero of the *Diana,* a whaler caught in the ice in Baffin Bay in 1866.

more to seal the ends of the world, at both these seasons the white wildernesses are traversed by innumerable channels. Thus the entire pack is in motion, but not in uniform motion. One ice island being relatively thin, moves to the bidding of the surface drift of the ocean, obeying the vagaries of the tides; another, of much greater thickness, having its roots in deeper water, rides relentlessly upon an undercurrent. So, even if the weather is calm and there have been no recent storms to disturb the distribution of pressure in the depths of the pack, the moving pack is always perilous. The noise of the colliding ice, heard afar off in calm weather, has been likened to the ceaseless growl of distant thunder and to the roar of a stormy coast. Here are millions and millions of tons of ice in vast masses grinding, straining, charging at the bidding of winds and currents, day after day, week after week—an eternal conflict in which the stoutest ship is as frail a thing as a match-box. Polar vessels are so built that if they happen to be nipped between two converging floes they rise bodily out of the water. A whale-ship is pinched up, high and dry, but at least into comparative safety, much as you might push up a rounded object by the pressure of finger and thumb. Yet, no ship is ever really safe in pack-ice. As the pressure ridges formed by the twisting up of the edges of contorted floes rise higher and higher, great blocks of ice, many tons in weight, are flung into the air as though ejected by some unseen volcano.

The destruction of Sir Ernest Shackleton's hopes and the abandonment of all his plans for crossing the Antarctic continent from sea to sea is such recent history that you probably do not need to be reminded of that sad episode in the story of the Great White South. I refer to it here only because it followed from the loss of his ship, the *Endurance*, and illustrates the peril of the pack. The *En-*

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THE FREEZING OF THE SEA

" Pancake " Ice at Cape Adare, Antarctica

Reproduced by courtesy of The Scott Polar Research Institute

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durance, you will remember, drifted in the pack-ice in the Weddell Sea throughout the winter of 1915. When spring came, and with it a new troubling of the pack, the *Endurance* was so badly squeezed and strained, stout little ship though she was, that all on board felt that she was doomed. At last there came a day when the decks were thrust upwards and she began to grind to pieces with a noise like gunfire. That was the beginning of the end. Shackleton and his men camped on the drifting floe a mile and a half from the wreck of their ship, and there the leader laid plans for the 800-mile journey to Elephant Island. In all the perilous adventures in search of polar knowledge there is none to surpass the return of this ill-starred expedition.

It is hard to think of the limitless steely floes, of the terrific conflict of the pack, the fog, the deadly cold implied by 90 or 100 degrees of frost,[1] the appalling conditions of the blizzards that ride on hurricanes—it is hard to think of a world of such cruel forces as holding anything of beauty or tranquillity. Yet of the many motives that have drawn men polewards again and again, in spite of all dangers and discomforts, the actual physical beauty of the frozen seas has always been a lure not less significant than love of gain or scientific achievement. All who have read much of polar exploration, in books by those who have had part in it, must have been impressed by the eagerness of the narrators to reveal the elation they felt in the presence of some wonderful picture built up of ice and snow. The colour of tropic seas is more vivid and abandoned, but not more marvellous or beautiful than of the seas around the Poles. On fine sunny days in summer there is a sparkle and a brilliance that gives a joy and zest to living even to the grumpiest and gloomiest. And as the sun skirts the

[1] 100° of frost equal −68° F. The lowest recorded temperature of the air at sea-level is −90° F., or 122° of frost.

horizon he " paints the white ice world with colour, with tints that are absolutely beyond conception if you have not seen them, and that no Ruskin can describe "—to quote Dr. William Bruce. " These beautiful scenes, so soft and so delicate "—adds this great polar authority—" produce impressions that can never be obliterated."

And here, too, are those other wonders, auroras—and icebergs. Though you may never visit polar regions, you still have a fair chance—if you voyage at all in temperate seas—of seeing the rotting carcass of some once splendid wanderer from the regions of everlasting ice. But icebergs are not sea ice, remember, but fragments of frozen continents, cast adrift to be carried on deep under-currents hundreds of miles—it may be thousands of miles—from the shores where they were launched. At the beginning of this chapter I spoke of the gigantic ice-caps covering the ends of the earth; we must return to them to see something of the origin of icebergs. Take first the Antarctic continent. The ice that covers it is constantly being added to. Practically all the precipitation is in the form of snow; there is no such thing as rain in the heart of Antarctica—say, once more, over an area as large as Russia in Europe and Australia combined. But it is nearly always snowing, and the snow becomes pressed into solid ice by the constantly increasing weight. The continent having a mountainous backbone, the massive ice-sheet, in thickness a thousand feet or more, is forced seawards in the most stupendous glaciers existing on earth to-day. It slides down the mountains, grinds across the plains, finally imparting impetus to the thinner ice-sheet bordering the coasts. This coastal ice—the fringes of the ice-cap—pushed ever from behind, becomes projected far out into the sea. Ultimately it comes afloat. Imagine the chalk cliffs of our own coasts thus pushed into the water; imagine the Isle of Wight, for

instance, an island of ice becoming detached from the mainland and floating free down Channel. It would represent the area of a modest Antarctic iceberg.

The marginal ice-fields from which bergs "calve" or break off are truly impressive. The great ice cliffs of the Ross Sea extend for a distance of nearly 300 miles. The Ross Barrier rises to a height of a hundred feet or more, and from it, as from similar cliffs in other Antarctic seas, the gigantic table-topped bergs of the Southern Ocean break off and float northwards. They are of all shapes and all sizes, but always flat-topped; until, becoming rotten, they split into smaller islands that capsize. The dazzling, resplendent cliffs of a large Antarctic berg extend for miles; capes, inlets, caverns in which the waves race and roar give them the semblance of ice-bound land. Bergs five miles long are common; ships may steam along their coasts for many hours, and though the stories of fifty-mile long bergs were once doubted, there is now no further room for doubt. A competent observer, Commander John Irving, who brought the Antarctic whaling research ship, *William Scoresby*, home to London in 1930, reported a meeting with an iceberg 150 miles long by 11 miles wide, whereof the cliffs were more than 300 feet high in places. Commander Irving had heard of this gigantic ice-island from Norwegian navigators, although when the *William Scoresby* encountered it, it had drifted many miles from the position in which it was previously observed.

So, there's your floating island, splendid to look upon, the most impressive thing you can meet at sea, with its wonderfully tinted cliffs towering a hundred feet above the water at its base. But its real base is far, far out of sight and reach. Only a ninth of its total thickness is visible above water. This island, of material as hard as flint, eight-ninths of it submerged, is not merely afloat, but actually

driven onwards, its motive power derived from a deep current far beneath the surface. No wonder it is impressive! It mocks at winds and tides and storms and surface currents. Lesser bergs are dashed to pieces in collision with it, it charges through the floe and rends a passage through the contorted pack as through obstacles of paper. It is irresistible.

Only in the South Atlantic and the South Pacific are these colossal icebergs to be encountered. Those born of the Arctic are pigmies in comparison, yet huge enough to be impressive when seen from the deck of a transatlantic liner. Consider again the contrast in the polar regions, the relative distribution of land and ocean. Nowhere in the Arctic is there to be found a terraced ice-sheet comparable to the Barriers of the Ross or the Weddell Seas, for nowhere is there comparable land for its formation. But the glaciers of Greenland and Spitzbergen feed the Arctic waters with bergs which come southwards on the Labrador Current, to the great peril of North Atlantic shipping. These huge bergs are peaked and castellated, quite unlike the flat-topped monsters of the south—of more fantastic outline altogether. The greatest danger from them comes in early summer, when they traverse the steamer lanes.

There is little hope for a ship that strikes a berg; it is striking rock, remember. And to add to the danger and difficulty of navigation when the bergs are riding to dissolution on the Labrador Current come mists to shroud their passing. The enormous masses of ice melting in water of a much higher temperature bring with them conditions like those when the moisture of our breath becomes visible on a cold, damp day. The mixture of two portions of moisture-laden air at different temperatures generates fog. Ever since the awful *Titanic* disaster in 1912, there

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THE BEAUTY OF THE FROZEN SEAS

Seals and penguins on an ice-floe drifting past the sea-face of an intensely crevassed glacier, Enderby Land, Antarctica

From a photograph taken during the B.A.N.Z. Mawson Expedition in the " Discovery "

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has been an Atlantic Ice Patrol, based on the American shore, which gives warning of the area and direction in which bergs are travelling. But in spite of the invaluable service rendered to shipping by the Ice Patrol, the iceberg peril in the North Atlantic remains a real one. In some years the conditions are worse than in others, but the liner captains generally have anxious voyages when heavy ice is reported off the eastern edge of the Grand Banks of Newfoundland. In 1929, a big, west-bound Leyland liner found herself surrounded by huge icebergs, which could be heard crashing in the darkness. For many hours she was in deadly danger, and only vigilance saved her from disaster.

How would you destroy an iceberg? All sorts of methods have been tried within recent years. You might fire a thousand tons of high explosives into it with little more effect than if you fired at granite. You can mine it in a hundred places with dynamite, without making much impression. A method growing in favour is to set up fierce internal strains by means of heat. There is a material called thermit, a mixture of powdered aluminium and iron oxide, that burns so fiercely that if a little be ignited on an iron plate it will instantly burn a hole right through. Thermit has been used to demolish icebergs. Holes are bored in the sides of the berg, the thermit inserted, and fired. In a little while the terrific heat sets up strains that cause the berg to crack, and finally to split into smaller and less dangerous pieces.

CHAPTER XIII

Divers and Diving Devices

When you swim down to recover the elusive shilling from the bottom of the swimming-bath, you are able to snatch what is, for most of us, the only possible experience of conditions under water. The water magnifies the coin, and although you can see it plainly enough, its position seems to change the nearer you approach it. In the sea you can descend to a greater depth, but that depends on your ability to hold your breath, and your strength as a swimmer, for the deeper you go the harder it becomes, and without a weight to help you down you will not be able to descend more than a few fathoms. You can never go far and you can never stay long, and in those respects you are in no degree superior to the first man who ever dived.

The notion that there lives in the east a race of men of singular aquatic powers, able to stay under water for five minutes or longer, is one of the strangest superstitions that still survives the assaults of science. The fact is that the most highly skilled pearl and sponge fishers cannot stay down more than two and a half or three minutes; most of them do not exceed two minutes, and sixty or ninety seconds seems to be the usual period of submersion. The probability is that the absurd exaggeration of the exploits of naked divers has arisen chiefly from the difficulty of accurate observation when the observer is watching some-

thing that interests him very much. He sees the pearl diver going overboard into shark-infested waters; he knows that every moment the diver stays down decreases the probability of his coming up again and the watcher's anxiety unconsciously magnifies the interval before his reappearance.

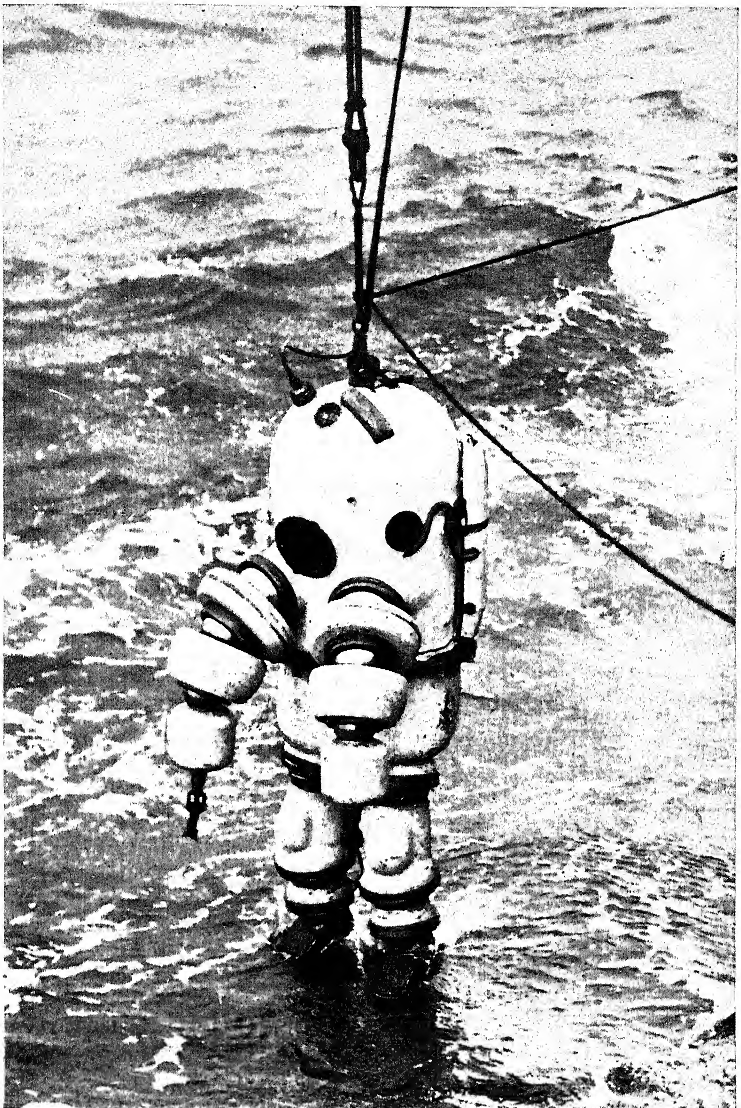
Man is an inquisitive animal. The mystery of the underwater world that could only be reached with difficulty and danger must have appealed to him from the moment when he first tried to penetrate it. The trophies of his diving exploits soon acquired a special and particular value. Mystic and magical properties becoming ascribed to certain of the diver's finds, such as the red or "precious" coral of the eastern Mediterranean, increased the demand for those things, and so established a trade in them that has survived to our own time. Thus with pearls, which were precious for the magic men imagined in them for thousands of years before their beauty and rarity made them desirable as ornaments and tokens of wealth and power. The ancient races that valued pearls most highly obtained their supplies mainly from sources that are still commercially important —those of Ceylon and the Persian Gulf. The pearl oysters of those waters have been ruthlessly exploited for thousands of years, and the methods of fishing by naked divers are in no degree different now from those of their predecessors in the day of Cleopatra—and a great deal earlier still.

At the appointed time the boats assemble, each with its complement of divers, and the diver proceeds exactly as did his forefathers through countless generations. The diver probably uses a metal clip to close his nostrils, but he may dispense with this aid. He invariably charges his blood with as much oxygen as possible by taking many deep breaths before he goes over the side of the boat. He is carried to the bottom by a large stone, weighing about

40 lb., attached to a rope with a loop through which passes his foot. This stone serves to hold him on the bottom, nine or ten fathoms down, while he detaches as many oysters as possible, feverishly scooping them into his net or basket in the few seconds before he must return to the surface to breathe again. When the water is no more than three or four fathoms deep he is able to dispense with his diving stone. There is no mention of it in Marco Polo's account of the Ceylon pearl fishery in 1292, though in all other respects that great book of travel describes the fishery practically as it survives now—even to the danger from sharks.

Because it has always been of high commercial importance—pearls are the most precious of the sea's natural treasures—the pearl fishing industry has in many places become highly organized. Merchants and divers were quick to see the possibilities of increased profits that would follow from the use of the diving-dress, and for a good many years the naked pearl diver has had to compete with rivals breathing compressed air and consequently able to send up many times more shell. Otherwise, the picturesque and animated business remains much as it has ever been. There are fisheries throughout tropical waters, from the Gulf of California—whence come most of the much-prized " black " pearls—to the east coast of Africa, from Ceylon to the coasts of Queensland and Torres Strait, from Madras to New Guinea. Pearling fleets work at periods which are strictly controlled by the laws of the countries concerned.

The oyster of the pearl fisher is quite unlike his succulent relative of Whitstable or Colchester, being in reality a kind of mussel, belonging to a genus known to zoology by the rather pleasing name *Margaritifera*. But different seas have different kinds of pearl-yielding molluscs, and nearly all bi-valve molluscs line their shells with the beautiful [illegible]descent substance known as mother-of-pearl, or nacre.



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DEEP-SEA DIVING

A diver being lowered into the Irish Sea in an attempt to reach a submarine sunk in 50 fathoms

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This substance, which gives a smooth, shining surface to the insides of the shells, is made by a secretion that is mainly carbonate of lime, with small proportions of organic matter. It is laid on in layer upon layer in extremely thin, semi-transparent films, and is identical in composition with the material of the largest and rarest pearls. You *may* find a pearl, either attached to the shell or lying free in the tissues, of any oyster; for any tiny foreign substance, such as a grain of sand, happening to work its way between the shell and the soft "mantle" soon becomes coated with the nacreous secretion.

It is surely a remarkable provision by which this animal, helpless to remove or expel an intruder or obstruction within its shell, is thus enabled to cover it up and render it harmless. As a matter of fact, however, the pearl-oyster can, in time, get rid of an intrusive foreign body, in the process of renewing its shell. An intruding substance such as a stone or a piece of seaweed, or perhaps a small shell of another mollusc, may be in time passed right through the shell of the oyster. The outside layers of the shell are continually decaying, and are ordinarily renewed by the secretion of equal layers of nacre outside as well as inside. But if there is a foreign body within the oyster more layers of nacre are deposited inside the shell, so that the oyster eventually builds itself a new cover, and from the decay of the outer shell layers the unwanted object slowly reappears on the outside of the shell. The Chinese take advantage of this process to make the oyster cover with mother-of-pearl little figures and images. These they slip below the fleshy "mantle" of the oyster and recover them when they are visible through the outside layers of shell. You can see such shells, containing little images of Buddha lying embedded side by side in nacre, at the Natural History Museum at South Kensington, London. So, too, the

Japanese produce "cultured" pearls by introducing into the oyster small bodies which after several years become so thoroughly coated with nacre as to be almost indistinguishable from true pearls.[1]

As to the cause of the formation of pearls, there is not yet absolute agreement. Pearls may, and probably always do, form around any irritant body which finds its way between the shell and the mantle, but—at least in the case of the Ceylon pearl oyster—the foundation is the egg of a parasitic worm. This worm lives in the intestines of a species of ray, a large and greedy fish of a type of which the skate is a familiar example. The eggs of the worms float in the sea until they finally settle on the bottom. Some drift into the shells of the oysters and lodge therein, so the oyster becomes the first host of this parasite. The oysters, however, are the favourite food of the rays, which cause terrible destruction to the beds, and thus—if it happens to be eaten—the oyster returns the worm-embryo to the ray. And if the oyster escapes being eaten, it must perforce entomb the egg of the worm in a beautiful sepulchre of nacre. So it comes about that the much-prized jewels of the sea originate in the strange life-cycle of a parasitic worm in a voracious fish.

The work of the naked pearl divers and sponge divers is the more wonderful when we remember that the weight of the water bearing on the diver's body increases by nearly half a ton for each foot he descends. At a depth of ten fathoms—the maximum depth at which he works—the weight of the water is between twenty-five and thirty tons, and the marvel is that he can do any work at all or even survive to dive again. Little wonder that the modern diving-dress has been brought to his aid! But it is certainly remark-

[1] Not to be confused with artificial pearls, which have nothing to do with oysters. They are thin glass beads coated with a solution prepared from the scales of certain fish.

able that the naked diver, still clinging to the methods of 3000 years and more, should be able to meet the competition of his better-equipped rivals, whose daily output of shell is about twenty times greater than his. And although science has recently done much to make deep-sea diving safer and easier, the diver is still strangely helpless in an unnatural element and his range of action absurdly limited.

As soon as there was any sort of engineering—bridges to be built with their piers in water, foundations to be carried down through water-logged ground to more solid strata—or as soon as ships became too large and unwieldy to haul upon the land without danger and difficulty; whichever of those conditions arose first there arose with them the need of divers. Sir Leonard Hill recently drew attention to the earliest recorded diving-dress. It is shown on a sculpture in the British Museum, nearly 2000 years old, which depicts men under water breathing from a skin full of air. But the earliest device of modern times, and the immediate forerunner of the compressed air caisson of the engineer, was the famous *cacabus aquaticus*, or aquatic kettle, which was used by two Greek divers at Toledo in Spain in 1538. If you put a wax night-light or a piece of candle on a wooden float in a basin of water and then invert a tumbler over it, pressing the tumbler down, the float and the candle will sink below the level of the water outside the tumbler. That was the principle of the aquatic kettle. The two Greeks inside were able to breathe and work just so long as there was any air left in their primitive diving-bell. As the candle would go out as soon as it had used up the oxygen in the tumbler, so the "divers" in the aquatic kettle would have expired if they had not been hauled up in time.

The famous Dr. Edmund Halley, mathematician and Astronomer Royal, is remembered chiefly for his working

out of the period of the return of the comet that now bears his name. His far greater claim to be remembered lies in his association with Sir Isaac Newton, whom he shepherded and sponsored and finally urged to publication of the immortal *Principia*. Newton was a very bashful, retiring genius, and we might have had to wait for many generations for the light his intellect disclosed if it had not been for Halley. Halley only concerns us here as the inventor of a superior kind of aquatic kettle—a diving-bell that survived in use practically until the days of compressed air. It was really no more than a large wooden chest, closed at the top but open at the bottom, lowered under water and held down by weights. The air supply came from weighted casks lowered with the bung-holes downwards and connected to the diving-bell by hoses. A diver wearing a waterproof leather dress and a small diving-bell over his head was able to go outside the main diving-bell and work there for a few minutes. That was in 1721. Some thirty years later a writer described a dress (used in an attempt to raise a wreck off the Isle of Wight) that must have borne a definite resemblance to the modern diving-dress. " They (the divers) are let down in a machine made of leather, strengthened at the knees and shoulders, and, if I mistake not, on the head, with brass. There are two leathern tubes to it—one for the air to go down, and to speak by, the other to pump out the air. They stay down for five minutes." [1]

The diving-dress of to-day is linked up with one of the great tragedies of naval history. In August, 1782, the *Royal George*, the largest and finest ship of the Line in the Navy, had been heeled-over at Portsmouth for repairs. You remember Cowper's lines, written at the time:

> " A land breeze shook the shrouds
> And she was overset."

[1] Dr. Richard Pococke, 1754.

Water poured in through the open ports and the *Royal George* sank with a loss of nearly nine hundred lives. For years afterwards she remained an obstruction to navigation and attempt after attempt was made to break up the wreck by men lowered in diving-bells. But the *Royal George* was a very large and stoutly-built ship, and even after she had lain under water for thirty-five years it was found impossible to dislodge her huge, staunch timbers. After the attempt in 1817 nothing more was done to dissipate the mighty hulk until 1839—fifty-seven years after the ship had sunk. It was then decided that it might be possible to blow up the wreck with enormous charges of gunpowder placed in the mud beneath it and fired by electricity. This attempt was successful, thanks to the inventive genius of one of the engineers employed on the task.

The engineer was Augustus Siebe. He had previously invented a helmet and breast-plate, connected by a pipe to an air-pump, which gave to the diver far greater freedom of movement than the clumsy diving-bell permitted, and enabled him to descend to greater depths. Boots weighted with lead held the diver to the bottom, and so long as he remained upright he was all right, the water being kept out of his helmet by the pressure of the air pumped into it. But because the lower part of his breast-plate was open, he couldn't stoop; if he did, the air rushed out and the water rushed in and drowned him. Siebe's dress for the *Royal George* operations in 1839 was a great improvement on his earlier one because it completely enclosed the diver. It was fundamentally the same as that which has remained in use ever since. A heavy metal helmet and breast-plate are joined to a watertight dress of strong canvas and rubber. It is important that the diver's hands should be free, but if the water is very cold he wears strong rubber gloves or ittens. His feet are encased in boots weighted with 40 lb.

of lead apiece; he has a leaden belt about his waist, and the total weight of his equipment is 200 lb. or more.

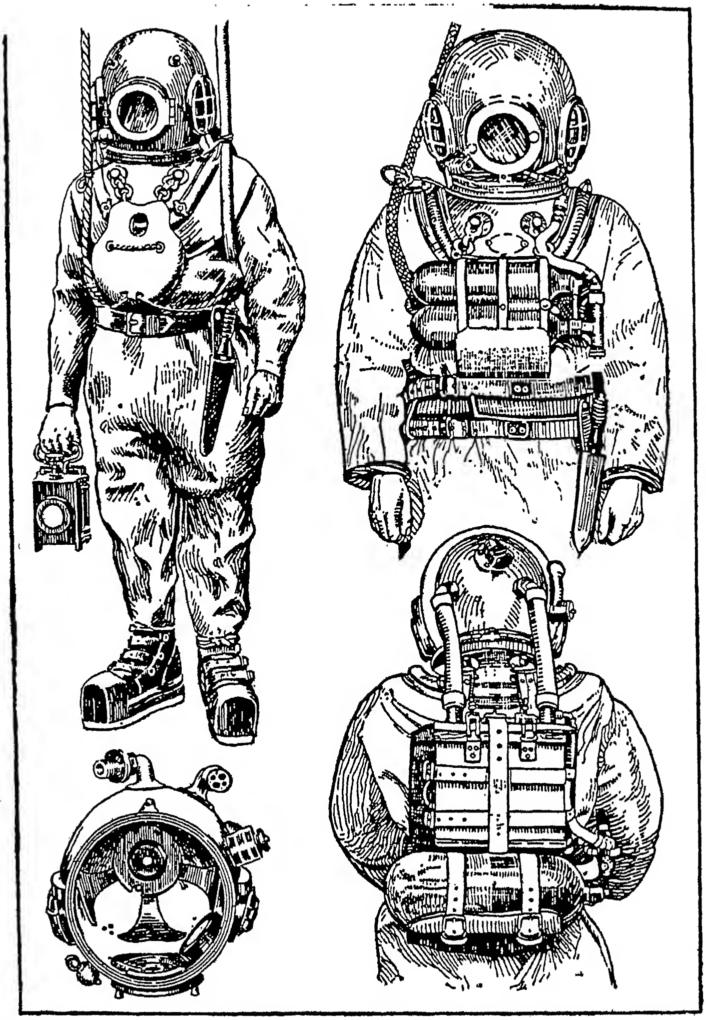
The weight and cumbrousness of his dress are but the beginning of the diver's troubles. In northern seas the water at depths of over a hundred feet is always disagreeably cold for prolonged immersion, and the diver first dons three thick suits of closely-knit underwear and three pairs of socks, to keep himself as warm as possible. Then assistants help him into his diving-dress. His feet are encouraged into the clumsy boots and the telephone receivers are adjusted to his head. Finally, the helmet is put on and fastened to the breast-plate, and thenceforward the diver must breathe the air sent into the helmet by the pump. Now so much encumbered that he can scarcely move, he is helped to the boat's side d lowered overboard. Attached to a cord at his waist is a strong sheath-knife—his only weapon. His connexion with his fellow-men lies in the life-line, in which is incorporated the telephone cable. This and the vital air-hose are very carefully paid out by the helpers as he descends. Wherever he goes and in all he does while under water, his first thought must be for the safety and security of these links with his natural world, for if they should become broken or entangled the diver in deep water is a doomed man.

The clicking of the pump valves above him changes to a roar as the air pressure increases with the depth, making it hard for the diver to hear any message in his telephone receiver. In spite of his great weight the diver is really absurdly light on the bottom, for his weight and the weight of the water are so nearly balanced that if he kicks at an object, or labours to move it, he bounces away like a man of indiarubber. Although his helmet has large windows, he cannot see more than a yard or two, and whatever object he looks at is magnified by the water. He has to learn to

work in the dark, doing everything by touch. Even powerful electric lamps do little to penetrate the gloom. If the bottom is hard it probably owes that condition to a current that adds to the diver's difficulties by tending to sweep him off his feet; and if it is soft, a cloud of fine mud rises to envelop him at every step he takes. All of what we may call the external conditions of his work are as unfavourable as they can be. Yet to darkness he can become accustomed, the roar in his helmet he can learn to tolerate, and he soon becomes as wary in his movements as an acrobat. But the very conditions that make his descent possible are those that most hamper and hinder him. It is only the pressure of the air pumped into his helmet that prevents him from being smashed into pulp by the weight of the water. Now, a man breathing air much above the normal atmospheric pressure is taking into his blood a much larger proportion of oxygen than his blood knows how to deal with.

The heaviness of water has been impressed on us a good many times in the preceding chapters, and we know that for every five fathoms of descent (thirty-three feet is the exact depth when the barometer measures 30 in.) an extra atmosphere is needed to balance the weight. A diver at a hundred feet therefore needs air compressed to three atmospheres; rather more than that, really, because extra air has to be pumped to him to raise the pressure in his helmet a little above that of the water. Take the case of the raising of the American submarine S.51 from a depth of 132 feet—a marvellous achievement that has been admirably recorded in a book that all who love pluck and perseverance ought to read.[1] The divers who salved S.51 had to breathe air compressed to five times the normal pressure. They were consequently inhaling five times the

[1] Commander Edward Ellsberg: *On the Bottom*, 1929.



Diving Dresses

On left: Ordinary diving dress and inside view of helmet. On right: Diver with self-contained diving apparatus

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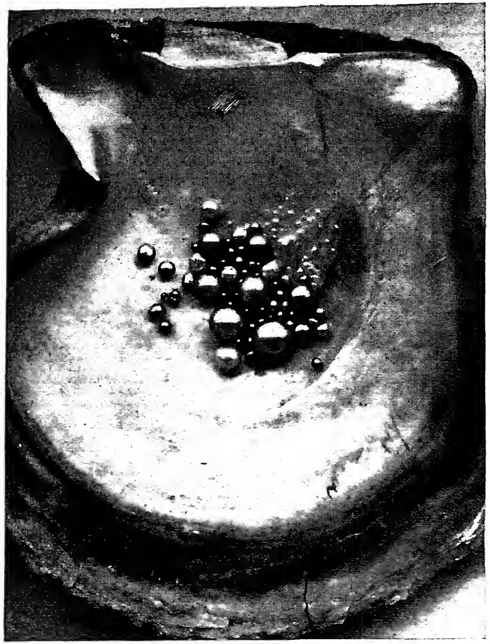


Pearl-shell with group of Golden Pearls

Southern Cross Pearl

E 328

PEARLS

From photographs by W. Saville Kent, F.Z.S.

Facing page 173.

normal amount of oxygen and nitrogen. The inert nitrogen is the gas which merely serves to dilute the vital oxygen to the degree at which our lungs are adapted to breathe it—four-fifths of the whole—but in excess it has an exceedingly harmful effect, as we shall see in a minute. And although we can safely breathe pure oxygen for a little while, a high concentration of this gas quickly becomes poisonous. Consequently, divers breathing air at five times its atmospheric concentration are under difficulties which make the external disabilities seem trivial in comparison. For one thing, the unnatural quantity of oxygen burns up the sugar in the blood much more quickly than it is meant to be burnt. Just as the extra oxygen sent into a fire by bellows makes the fire burn more brightly and more quickly, so are the diver's tissues consumed more quickly. One effect of this is to add to his physical weakness; another is to produce a state of exhilaration or intoxication, that, by making him light-headed, impairs his caution and presence of mind—the very qualities, in fact, that his perilous situation gives him the most need of.

The extent of the oxygen poisoning, however, is governed by the length of time the diver stays down and the extent to which he uses his muscles. If he is not down too long he suffers no harm. It is the nitrogen under pressure that is the main cause of the diver's troubles. Ever since men have worked in the unnatural conditions of compressed air, they have been subject to a strange disease known as "bends" or "caisson-sickness". Until recent scientific research showed the remedy, bends was the most dreaded enemy of deep-sea diving. It does not manifest itself until after the diver has returned to the surface, when he is liable to be seized by excruciating pains in the joints, or in the spinal column. Bends used often to lead to paralysis and sometimes death, and all workers in compressed air

went in fear of the dread disease. It is now known that bends is caused by nitrogen becoming absorbed in the blood while the diver is under pressure. Instead of all the nitrogen being exhaled, as it is in the ordinary way, some of it remains in the lungs and becomes dissolved in the blood. So long as the pressure is maintained, the nitrogen remains in solution—just as the carbonic acid gas in a bottle of soda water remains dissolved so long as the bottle is sealed. Until the seal of the soda-water bottle is removed there is no indication of the gas; it is dissolved in the liquid. There is an exact parallel in the case of the diver. So long as he remains under pressure the excess of nitrogen remains dissolved in his blood, but as soon as the pressure is removed by his coming to the surface the nitrogen resumes its gaseous state, effervescing and forming bubbles in the blood-vessels.

The discovery of the cause of bends, by pointing the way to the remedy, relieved diving—and for that matter all work in compressed air—of the worst of its terrors. The remedy lies in gradual decompression. By lifting him a little at a time from the depths at which he has been working, the diver is gradually brought under diminishing pressure, and the absorbed nitrogen finds its way out of his body. The slow decrease of pressure prevents the formation of bubbles, but the process is a terribly tedious one, the time it occupies depending on the air pressure necessary at the depth to which the diver has descended and the length of his stay on the bottom. If he has been working for an hour at a depth of 130 or 140 feet, it will take two hours to bring him to the surface. During the salving of the submarine S.51 two divers remained down for three hours and twenty minutes—the longest dive on record for deep water—nearly three and a half times the safe limit. Nine hours were occupied in decompressing them at different levels under water before they were finally

allowed to emerge, shivering and exhausted, after more than twelve hours in the chilly waters of the North Atlantic.

Deep-water diving can never be a pleasant business nor a safe one, though it has thrills enough and to spare for the more adventurous. Some of us—even those whose only motive is curiosity and love of new experiences—will no doubt venture under water before long, but our activities must be confined to warm seas and shallow. Needless to say, the diver who descends to the two hundred feet level, or even to half that depth, must be physically and mentally fitted for the work and thoroughly equipped by long training and experience. Most of what has been done to mitigate the dangers and discomforts of deep-sea diving is the outcome of scientific research and experiment. A quarter of a century ago a Deep Sea Diving Committee, experimenting for the British Admiralty, worked out tables showing the periods necessary for decompression for work at different depths and the length of time divers could safely remain down. More recently it has been found that by supplying the diver with what may be called artificial mixtures of oxygen and nitrogen, instead of the normal mixture, it is possible for him to descend to greater depths and to stay down longer. Two hundred and four feet used to be considered the maximum depth at which he could safely work, but only for a very short time. Now, however, he can go down to 300 feet in comparative safety.[1] The oxygen in the air supplied to him is reduced in proportion to the depth, so that he breathes a more normal mixture. When he begins to ascend the proportion of oxygen is gradually increased until, as he nears the surface, he is made to breathe pure oxygen. One result of supplying divers with such

[1] It was stated in evidence in the High Courts in 1930 that the latest Admiralty tests had shown that a depth of 340 feet had been reached with the ordinary diving-suit. At that depth a diver could stay 10 minutes.

artificial air, carefully adjusted to suit their needs at different pressures, has been to reduce very much the time taken in the dreary process of decompression.

To this improvement British scientists have quite lately added another having for its object the greater comfort of divers. In the usual practice of decompression the diver is hauled up by his life-line to the level of a stage or platform lowered into the water. The diver climbs on to the stage and waits there during the first part of the decompression period, after which it is hauled up to a higher level, at which he completes the period. Thus he has to remain imprisoned in his awkward dress, surrounded by the cold, dark, cheerless water, for hours after his work on the bottom is done. Now, however—at least if he is a diver in the British Navy—he is able to enter a decompression chamber, in which the tedious business of returning to normal air pressure is far more comfortable than it used to be. This chamber is a strong steel cylinder, fitted with telephone and electric light, which the diver enters at a depth of sixty-six feet. An attendant inside relieves him of his helmet, the chamber is hoisted to the deck of the diving vessel, and decompression goes on in relatively pleasant conditions.

It is in the recovery of treasure from sunken ships, occasionally in the salving of the more portable and usable parts of them, that the most sensational diving exploits have been accomplished. The salving of a wreck in shallow water is child's play compared with any attempt to recover valuables from a ship sunk in more than a hundred feet of water. Consider the circumstances. A diver in deep water is in a position of scarcely believable isolation and helplessness. His physical disabilities must needs be counteracted, if he is to accomplish anything at all, by an increase in mental alertness; he must possess courage and be trained to quickness of mind quite beyond the ordinary. Imagine

the diver groping his way along the slippery, sloping hull of a wreck lying at an angle on the bottom, foothold and handhold alike precarious, currents making it difficult to move or darkness making it difficult to see. If he slips into deeper water the sudden increase of the water pressure may crush him into his helmet, squeezing him to death in an irresistible vice. If his air-hose and life-line become fouled in wreckage, and there is no companion near at hand to free them, his only hope of escape lies in closing his valves and severing the entangled hose and line. Then, by releasing his lead belt, he will rise to the surface. But suppose the obstruction occurs in the dark labyrinth of the sunken vessel's interior—a trap from which there is no hope of escape! If his suit tears on the sharp, broken edges of ruptured plates or splintered gear, the air will rush out and the water rush in, and the diver will be drowned unless he can be hauled to the surface in time. In such case, the terrific weight depending from life-line and hose, once the buoyancy has gone, tends to sever the helmet and breast-plate from the dress, so that they may part completely, leaving the helpless diver to sink like a stone. Such accidents have happened.

But a more frequent cause of disaster is due to particles of grit or sand working into the exhaust valve and preventing it from opening. When his exhaust valve ceases to function, the diver's dress blows out with the increased air pressure, and " spread-eagled " he shoots to the surface like a rocket. He is rescued bleeding at nose and mouth and hurried at once to the " iron doctor ", a recompression chamber on every diving ship, in which a diver suffering from bends, or in danger of attack by that ghastly complaint, is once again subjected to pressure and then gradually decompressed.

Probably the most famous name in the story of diving is that of Alexander Lambert. It was he who, in the face

of tremendous difficulties, succeeded in closing an essential valve in the flooded workings of the Severn Tunnel. Even more sensational was Lambert's recovery of the specie from the *Alfonso XII*, a steamer that went down in 1855 off Las Palmas. The specie, to the value of £70,000, was in the steamer's strong-room, and lay in 165 feet of water. All the gold was brought up by Lambert, who made two or three descents a day. But on his last dive on this wreck he stayed down for three-quarters of an hour, instead of the usual twenty minutes, and the result was an attack of bends, leading to spinal paralysis, from which this great diver never recovered.

Perhaps no more appropriate commentary on man's powerlessness to approach the under-water world could be found than a comparison of Lambert's famous exploit of forty-five years ago and the most sensational achievement of modern divers. After Lambert's time a Spanish diver salved a cargo of silver bars from a wreck in 182 feet of water. In 1906, a Mr. Catto, working experimentally for the Deep Sea Diving Committee, attained a depth of 210 feet. But the greatest depth from which treasure has ever been recovered is 240 feet—only 75 feet deeper than the water in which Lambert worked. It was at that depth that an Italian firm in 1928 salved the valuables in the cargo of the *Elizabethville*, a Belgian liner sunk by a German submarine off Belle Isle, Brittany.

It is true that the "Iron Man" can descend to much greater depths; but because that contrivance of German inventive skill completely lacks the power to move, its range of usefulness under water is very seriously limited. In some respects the Iron Man is an improvement on the compressed air diving-suit. The diver therein breathes air at ordinary pressure. It is really no more than a steel shell, strong enough to resist the water pressure, lowered

to the bottom by chains. Cylindrical limbs are fitted to the trunk with ball-bearing joints, and the arms terminate in scissors-like grabs that can be operated from the inside. The whole contrivance is very ingenious and carefully thought out, but the diver's movements, and particularly his power to use his hands, are so much restricted, that his function can be little more than to guide and fix chains and mechanical grabs sent down to him from above.

Yet in spite of these disadvantages very encouraging work has been done with the Iron Man at far greater depths than is possible with the compressed air dress. In 1929, a diver descended to 71 fathoms—426 feet—and stayed down for an hour and three-quarters. At that depth the water pressure is equal to 13 atmospheres, or 182 lb. to the square inch. The diver, of course, was quite unconscious of this pressure, since he was breathing ordinary air. There was therefore no necessity for any process of decompression, and he was able to emerge immediately from his shell, a perfectly normal man.

The depths it is possible to attain in the Iron Man, sensational though they sound in comparison with descents in the conventional diving-dress, are completely dwarfed by the record established in the summer of 1930 by two American scientists. These pioneers in the human exploration of the depths of the ocean were Mr. William Beebe, Director of the Department of Tropical Research of the New York Zoological Society, and Mr. Otis Barton, of the New York Museum. In a steel globe, fitted with windows, they allowed themselves to be lowered in the clear waters off Bermuda, to a depth of 800 feet. But they were not content with that record—nearly twice the depth to which man had ever penetrated the waters—but a few days later Mr. Beebe and Mr. Barton descended again, this time to a depth of 1426 feet. They reported that they

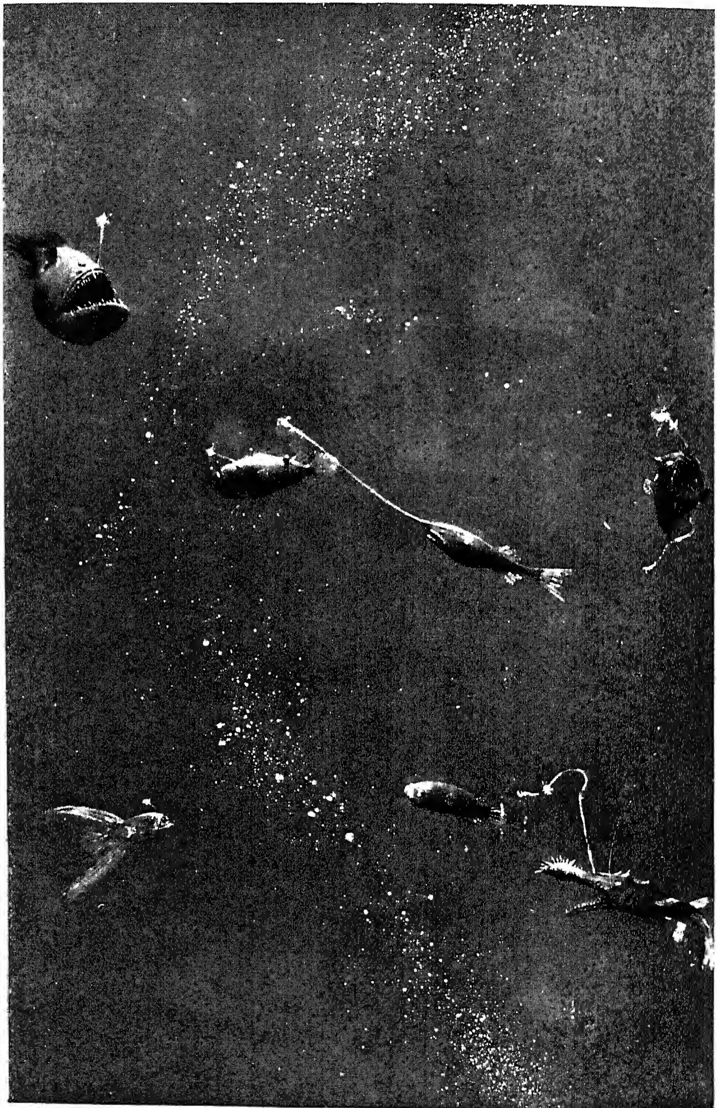
suffered no discomfort, and that the experience was tremendously interesting. Fish were readily observed in the blue-violet light, the rest of the spectrum being cut off.

Mr. William Beebe is no novice at diving. He is, indeed, a vigorous champion of its charms as a recreation. His books are worth reading by all who love the sea, for he exemplifies that rare combination—a mind drenched in science, and imagination that finds expression in a charming and graphic literary style. Here is a quotation from him that seems appropriate:

"All I ask of each reader is this—don't die without having borrowed, stolen, purchased, or made a helmet of sorts, to glimpse for yourself this new world. Books, aquaria, and glass-bottomed boats are, to such an experience, only what a time-table is to an actual tour, or what a dried, dusty bit of coral in the what-not in the best parlor is to this unsuspected realm of gorgeous life and color existing with us to-day on the self-same planet Earth." [1]

Well, that's my notion too. I don't see why self-contained diving-helmets shouldn't come into use as a new seaside experience for most of us. There are light waterproof suits with a helmet containing soda-lime to absorb the exhaled carbonic acid, with vessels of compressed air or oxygen, that are entirely reliable in shallow water. The management of the various valves is easily mastered. Indeed, I see only one objection. The waters about our coasts are a trifle too chilly for really comfortable submarine rambles.

[1] William Beebe, Sc.D.: *Beneath Tropic Seas*.



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LITTLE SEA-DEVILS

Deep-sea fishes that attract their prey by the luminous tip of a rod

Reproduced by courtesy of The American Museum of Natural History, New York

Facing page 181.

CHAPTER XIV

Life in the Depths

All the creatures that dwell in the sea are extremely odd to look at. No doubt, if there were such a thing as an intelligent fish, able to take an occasional survey of the beasts and birds and insects of the dry land, he would come to much the same conclusion regarding their appearance. Yet the oddness of the sea beasts is a great deal more than skin deep, and that is one of the reasons why the study of their peculiarities is one of extraordinary fascination. Marine life bristles with puzzles and phenomena of quite uncommon interest, and in this short chapter I am going to touch on some of the very remarkable conditions of life in the depths.

We should naturally expect to find in the animals inhabiting the sea the same power of adaptability that we so constantly recognize in land animals. Indeed, this power is nowhere better exemplified than in the creatures of the sea. The marine animals have developed a bewildering variety of highly specialized organs and functions, without which they would have been unable to survive in the fierce struggle for existence. "Eat or be eaten" is the law of the sea-realms, in which, large as they are, there would be no room for any animal that had escaped the influence of specialization.

The extraordinary fecundity of many fishes, that is, their power of reproduction, as of many humbler sea animals,

is an example of this. Some of the most valuable food fishes—ling, cod, turbot, for instance, survive on the principle that there is safety in numbers. They lay their eggs in millions, out of which, in the ordinary hazards of the sea, only a ridiculously small proportion—so it seems to us—will survive to lay eggs in their turn. A ling may lay twenty million eggs or more, a turbot up to eight million, a cod nearly as many. These eggs drift idly in the sea, food material for hosts of ravenous animals. Those that escape being gobbled up hatch out into diminutive creatures, generally quite unlike their parents, that are at the mercy of enemies both animate and inanimate. Not more than two or three out of every million, so we are told, escape all the perils of a fishy childhood. Yet there are so many that some are bound to grow up.

Egg-case of Dog-fish

At the other end of the scale are fishes that are very sparing with their eggs, and in consequence have to guard them very carefully. Instead of casting them adrift in reckless millions, such fishes have, in some cases, developed remarkable ways of protecting them. The " mermaids' purses " of the seashore, the curious little leathery envelopes that you have probably found when walking on the beach, are the egg-cases of the dog-fish and the skate. The skate's is the larger, with two short projections at one end, and two long, curved, horny " arms " at the other. The skate's egg lies safely out of harm's way in this tough " purse ", buried beneath the sand. The dog-fish eggs are rather smaller, and are equipped with strong, wiry tendrils—just like the tendrils of the vine—which Mr. and Mrs. Dog-fish carefully wind round the stem of a seaweed. Thus securely attached the precious egg is comparatively safe,

and the parents take no further interest in it. But a few fishes go a step further and jealously guard the eggs, and afterwards the young. Some species of wrasse, a type represented by brightly coloured little fish that sometimes get sent to table, make nests of seaweed for the protection of their eggs, a habit they share with the better-known stickleback; and a good many fish make sanctuaries for their eggs, of a simpler kind. Those strange fellows, the gentlemen pipe-fish (page 53) and their still stranger relatives, the sea-horses, carry their spouses' eggs in their tail-pockets. There are even a few species of fish, mostly belonging to the shark tribe, in which the young are born alive, instead of being hatched from eggs laid externally.

And now, to turn to another respect in which the marine animals show endless adaptation, have a look at fins. The fishmonger's slab is not usually considered one of the most interesting features of our streets, though it well might be. Very few of us can resist the attractions of a taxidermist's window, and a shop with a show-case of butterflies always secures attention from passers-by. The fishmonger offers every day a similar "exhibit" in most enthralling natural history, but most people pass it unheeding. Probably if you gazed at his display with too rapt attention, he would think you had designs on the kippers. But the astonishing differences in the shapes, colours, contours, and other visible characteristics of his wares, the size and arrangement of the fins, and even the scales, would undoubtedly prove an interesting study.

From the accompanying diagram you can see the typical arrangement of a fish's fins. Some of these fins are paired; that is, the pectoral and ventral fins are present on both sides of the body and are equivalent to the limbs of the mammals and birds. Now, look at the manner in which the fins have become modified in different kinds of fish. Take

the mackerel for a start, and compare it with its distant relative, the angel-fish. The form of the mackerel is most beautifully adapted for rapid movement in water. Its torpedo shape, its perfect "stream-lines", may be taken as the best model on which any underwater craft can be designed. The form of the mackerel certainly supports the belief that it is the fastest swimmer among fish, though the statement that it can travel at a speed of sixty miles an hour would be hardly credible if it came from a less reliable authority than the United States Fisheries Commission. Certainly the

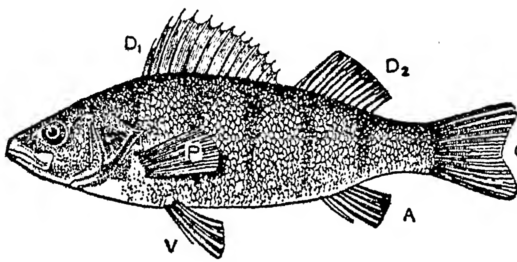
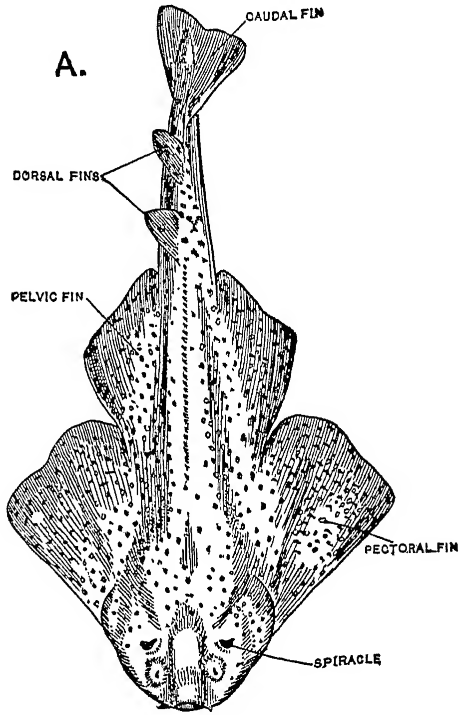


Diagram of a Fish to show Fins
D_1, First Dorsal. D_2, Second Dorsal. P, Pectoral. A, Anal.
V, Ventral. C, Caudal.

mackerel can swim faster than those terrific expresses of the seas, the true sharks, though they also have acquired the ideal spindle shape that offers the least possible resistance to the friction of the water.

But what can be said of the angel-fish, except that it is ugly and ill-named? There is no suggestion of speed in this creature, which is also known in some parts of Britain as the monk-fish. The form has been flattened from above, downwards, as in the skates, not sideways as in the true flat-fish, on which it preys. And what has become of the neat pectoral fins of the mackerel, or of its cousin the shark? They are no longer neat, but have grown into the huge, ungainly "wings" that once suggested, I suppose,

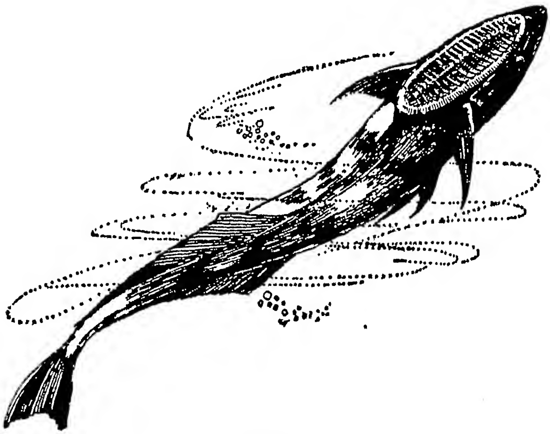
a likeness to a very unprepossessing kind of angel. But, no doubt, the angel-fish finds the strange development of his pectoral fins very satisfactory for flopping over the sandy bottoms in his search for flat-fish. We may be sure that they were necessary for his survival, for the slow swimming fish and the sluggish fish, have evolved the forms and features best suited to their particular needs, just as the swift and active ones have.



Angel-fish

There are very many ways in which fins are modified, but we can only stop to consider a few of them. Take the several sorts of sucking fish, in which the fins have developed into plates or discs for exerting a strong vacuum suction, thus enabling these fish to glue themselves to a firm holdfast in a strong current. The little gobies of the English rock-pools would be battered to pieces on the rocks, or carried away by the undertow, if they were without the adhesive discs that have been formed by the uniting of the ventral fins. In the lumpsucker, too, a large, clumsy,

and grotesque fish, but a beautifully coloured fellow, none the less, the ventral fins have become united by a membrane into a powerful suctorial disc. The sucking fish of greatest interest, however, is the remora. This fish, which is distributed in tropical and sub-tropical waters, from the West Indies to the China Sea, may be said to have developed laziness to a fine art. Although its shape, fins, and muscular power are all well adapted to an active life, Nature h



Remora

evolved for it an apparatus that saves it a vast amount of hard work. The top of the remora's head is equipped with a very remarkable sucker, with which it attaches itself to the bodies of large fish—generally sharks. Thereby it secures free transport, and doubtless a share in its host's food, but it does not appear to render any service to the shark in return for these advantages. So firmly does the remora adhere, that it has for long been used for fishing. Natives catch the remoras, attach lines to their tails, and then throw them overboard in the vicinity of the fish they w t to catch, knowing that the remora cannot resist the instinct

to attach itself, even when tied by the tail. In this way the remora is a valuable assistant to the turtle fishers of Torres Strait and elsewhere; and as he is quite good to eat, he generally goes into the pot himself at the end of a day's fishing.

Since the remora carries the sucking disc on the top of his head, it clearly cannot be a modification of the ventral fins, like the suckers of the gobi or the lumpsucker. It is, indeed, hard to find any connexion with fins, at first sight, for the organ looks just like a grating, or the tread of a motor tyre, or a very stout rubber sole of a countryman's boot. But it is really a development of the back, or dorsal fin. In the infant stages of the fish this fin is like that of any other fish, and only changes its form and position, and ultimately its function as the fish grows up.


Gurnard

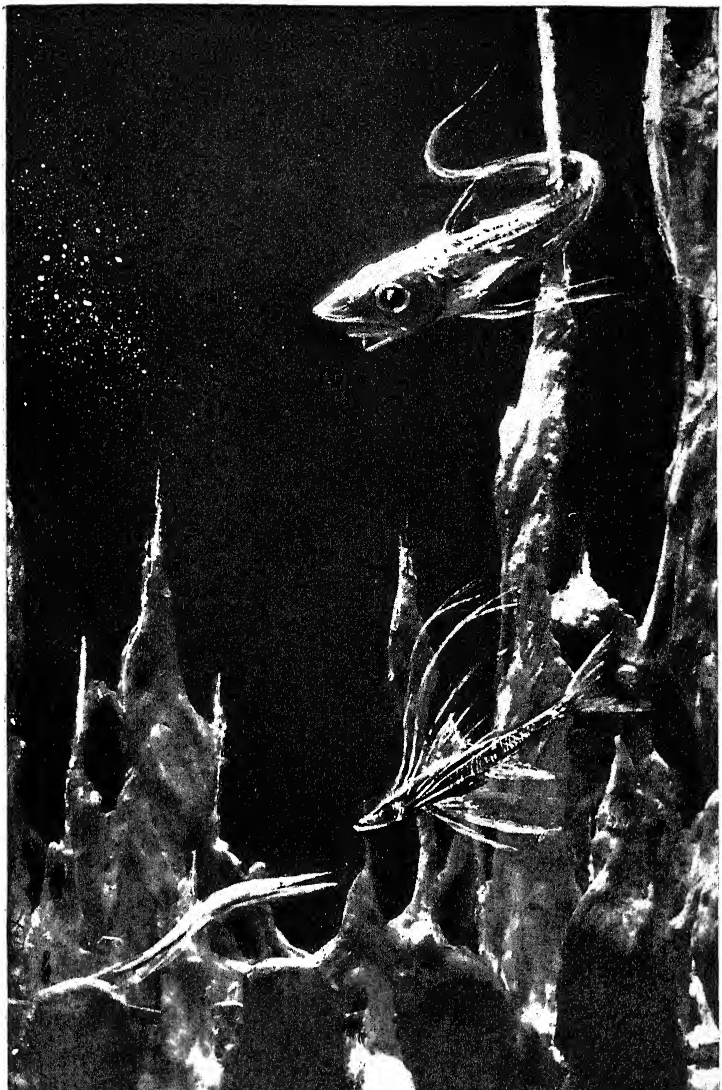
Sometimes the pectoral fins are adapted for climbing or crawling. Ask your fishmonger for a gurnard—he has one from time to time—and before it is cut up for cooking, have a look at its extraordinary " legs ". Here's a fish that walks. He's a remarkable character altogether, and not at all pretty to look at. But the oddest thing about him is the way in which the " bones " or fin-rays, as they are called, of the pectoral fins have become quite separated into legs—three on either side—to provide him with a distinct method of locomotion. Another uncommon mode of progression is employed by the little blennies of British shores. These fish, representatives of a large and spiny family which

includes the formidable cat-fish and the butterfly-fish, employ projections on the ventral fins for clambering over the seaweed when the tide is out. So too, does the tropical bommi, or mud-skipper, but in this fish the clambering has become climbing, and the ventral fins have grown to be almost like arms, with appendages that might easily be taken for hands with webbed fingers. It is said that the bommi can even climb trees. The climbing fish

Bo ' or " Mud-skipper "

have a second peculiarity, and a very necessary one, in their power to live out of water for quite a considerable time.

So we see that out of the normal functions of fins, which we may take to be swimming and steering, laterally and vertically, other functions have come into being, such as holding fast, crawling, climbing. The catalogue of adaptation might be extended very much farther, but we must be content with two or three more examples. One of the most enchanting sights that you can come upon at sea, is a shoal of flying-fish. The graceful creatures, gleaming like silver in the sunshine, spring upwards from the crests of waves and dart in skimming flight over the intense blue



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GOBLINS OF THE OCEAN ABYSSES

A group of deep-sea fish

Reproduced by courtesy of The American Museum of Natural History, New York

Facing page 188.

of the tropic seas. It is hard to believe, in watching them, that their wings are only exaggerated pectoral fins, for there seems to be distinct vibratory movement, so rapid that the fish appears to be enveloped in a cloud of mist. Yet the flight is not true flight, in the bird sense; and though the "wings" undoubtedly do move and may impart some independent motion to the flying-fish, nearly all the impetus is probably derived from the initial leap from the water, in which the broad tail plays an important part. Naturalists are not unanimous on the exact method of the flying-fish's darting flight, nor whether the huge pectoral fins are used for propulsion, or merely serve as planes to maintain equilibrium while in the air. There is no doubt, however, that these fish have developed their wings as a means of escape from their enemies, chief of which is the magnificent fish known to zoology as *Coryphærna hipuris*, and to sailors—wrongly, it seems—as the dolphin. I have said something about the true dolphin in another chapter (page 217). I want you here to notice that the sailor's dolphin is able to take great leaps out of the water and so can catch many flying-fish "on the wing". But some of the graceful little fugitives are bound to escape, because, although their pursuers can leap, they have no power to fly.

Flying-fish

The hereditary enemy of the beautiful flying-fish has always been popular with sailors because it seems to have an affinity for ships and will play round them in fair weather for the great part of the day. The late Frank Bullen, one of the most delightful writers ever recruited from amon

seamen, and a shrewd observer of sea life, has left such a vivid picture of the sailor's dolphin that I cannot forbear to quote it:

"No pen could possibly do justice to the magnificence of their colouring, for, like 'shot' silk or the glowing tints of the humming-bird, it changes with every turn. And when the fish is disporting under a blazing sun, its glories are almost too brilliant for the unshaded eye; one feels the need of smoked glasses through which to view them. These wonderful tints begin to fade as soon as the fish is caught, and although there is a series of waves of colour that ebb and flow about the dying creature, the beauty of the living body is never even remotely approached again, in spite of what numberless writers have said to the contrary. To see the dolphin in full chase after a flying-fish, leaping like a glorious arrow forty feet at each lateral bound through the sunshine, is a vision worth remembering. I know nothing more gorgeous under heaven."

And now, by way of contrast, let us have another glance at the pipe-fish, a marine oddity that has commanded our notice two or three times already. He is a representative of a truly remarkable family; he looks, perhaps, as little like a fish as a fish can look—or should we say *ought* to look, since the truth is that fish show so many departures from conventional form that we are not surprised to find them looking like bottles, butterflies, or balloons. But here's a pipe-like fish with a tubular, toothless mouth that it cannot open, a skin covered with hard plates of armour instead of scales, a pouch for hatching its eggs (a privilege reserved by the gentlemen), the merest apology for tail fin and dorsal fin and only vestiges of the other fins. This unconventional fish has for its cousin one more singular still—the sea-horse. Here the tail fin has vanished entirely, and the fish has to propel himself by rapid vibrations of

the dorsal fin. Why? Well, I hardly like to say so, for the sea-horse is a most engaging little creature, but I fear he grew lazy. Swimming tired him, and he took to coiling his long pipe-like tail about the stems of seaweeds, and using it as a holdfast while waiting for his dinner to drift by. And finding that it came to him without effort on his part, thus he stayed, in a vertical position, with his chest puffed out and his queerly-shaped head held at right angles to his body, in the remarkable attitude that earned him his name. Swimming became more and more irksome, and now, when he needs to change his quarters, it is a serious business, for he has to wind up his tail in a coil like a watch-spring before he can use his dorsal fin for swimming.

Sea-horse

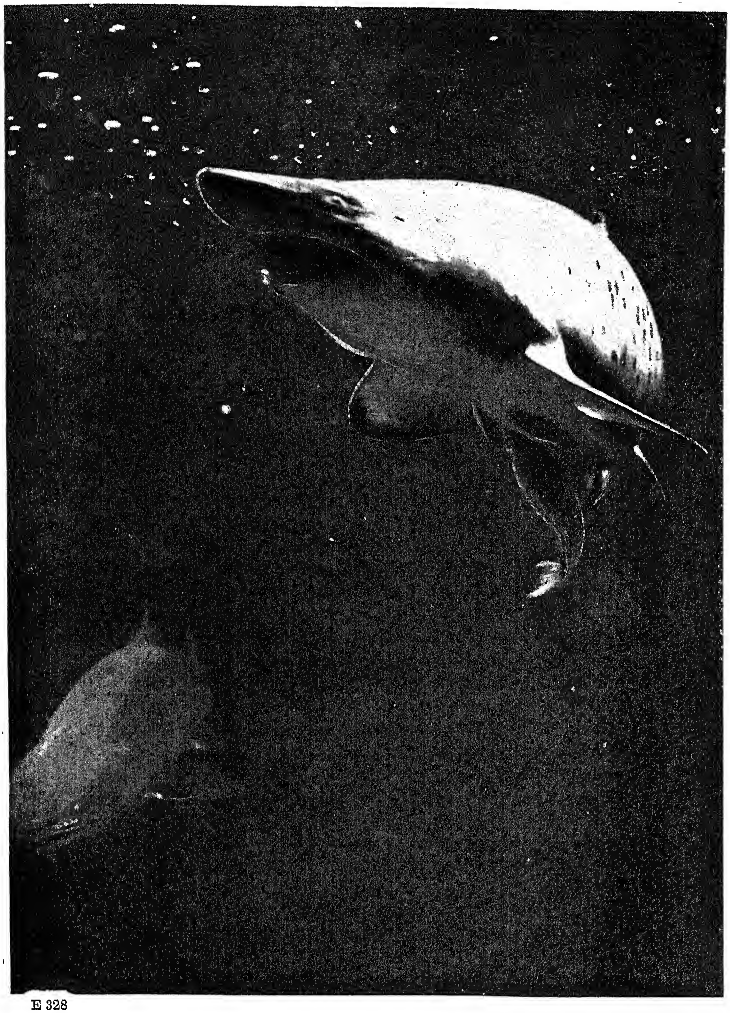
Like many other sea-creatures that are without the power of escaping from their enemies by rapid flight, sea-horses have developed in form and colouring an admirable likeness to their surroundings. They are exceedingly hard to find in their weedy retreats. Their relatives the sea-dragons would seem, however, to have rather overdone this scheme of protective camouflage. They have dressed themselves up in the most weird and astonishing trappings, designed to look like seaweed. These are outgrowths of their skin, tatters and frills and lobes growing out of all parts of their bodies. Yet we need not wonder

at that, since so many of the less active sea-creatures have dire need to efface themselves from the ravenous search of their enemies. Possibly you have heard of the crabs that "decorate" themselves. Here is a scientist's account of how it is done:

"Whenever we felt the need of a humorous touch in science, it sufficed to pry loose several of these crabs and

Sea-dragon

put them on view in an aquarium. Within a few seconds after regaining their balance, they would cling together as closely as the proverbial burr or tar baby, and would begin to filch seaweed from one another and landscape-garden themselves. With eyes comically raised they would reach out with their claws, feel among the growths on the back of one of their fellows, and pluck a bit of weed. The broken end was then placed in their mouth, probably to moisten it with a sticky secretion, and it was then solemnly



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SHARK PHOTOGRAPHED IN ITS NATIVE ELEMENT

An underseas snap-shot taken in the Atlantic near the Bahamas

Facing page 192.

planted on some shady portion of their anatomy, where the crop was not doing so well. The comedy of it was only enhanced by the seriousness of the operation, creatures with no means of defence endeavouring to efface themselves by transplanting seaweed, sponges, sea-anemones, anything which they could move and which would take root on the hard, rough surface of their body." [1]

Fish graceful and fish grotesque, gaudy fish and dowdy fish—whichever way we turn to look at them, they are full of surprises for us. And that is true of all forms of sea life. The fish, though the most numerous of the vertebrate sea-animals—animals with a skeleton of bone or cartilage and a highly-developed head and brain—really comprise a very small proportion of the sea population. Yet the kinds of fish far outnumber all the other vertebrate classes—mammals, birds, and reptiles. We think there are a lot of different mammals in the world—there are about 2400 species—but the species of fish outnumber the species of mammals by more than eight to one.

There are so many points of interest about the living things in the depths, that I can do no more than hint at a few of them. Two of the most interesting things are the ability of some sea-animals to change their colour schemes to suit their surroundings, and the property of phosphorescence that is common to a still larger number. The colour changes are clearly protective; they enable the animals to become as inconspicuous as possible, and so less likely to be observed by their enemies. It is even suggested that, in the case of fish, their ordinary colours and patterns —their workaday dresses—have been evolved to render them as little visible as they can be made. You can see how terribly out of place one of our muddy-coloured northern fish would appear in the gorgeous coral-groves of the

[1] William Beebe: *Beneath Tropic Seas.*

tropics, and how the same would be true of a gaily-dressed fish transported to the dark rocks of our coasts. And though our fish are for the most part soberly clad, some of them can change their colours to match their homes, though this power is naturally better developed in the gayer fish of warmer seas. In a few fish the colour changes might almost be described as emotional, fluctuations of colour sweeping across their bodies in a most wonderful way, as though in response to changes in their feelings.

Phosphorescence is a much commoner attribute of marine life than most people suppose. You have very probably seen the beautiful effect of a phosphorescent sea on a dark night, when the rippling water is set with millions of tiny stars and points of greenish-blue light. In seas warmer than our own, the phosphorescence is often sufficient to make the water seem alight with a strange unearthly glow. Breaking waves are cascades of fire, and the wake of a boat is like a lighted brand drawn through the water. Sometimes this effect is very pronounced even in English waters, and I can remember a dark night off the Isle of Sheppey, when the passing steamers trailed fiery chains astern, and I hauled up bucketful after bucketful of sea-water just for the sheer joy of tipping back into the sea fountains of cold fire of a lovely pale blue.

Phosphorescence is rather a bad name for this phenomenon, which has nothing to do with phosphorus, except a general resemblance to the glow of common phosphorus in the dark. It is better to call it luminescence, or better still, bio-luminescence, since it is an attribute of living organisms. Much of the luminescence of sea-water is due to the presence of enormous numbers of one-celled organisms called noctiluca. Science is not quite sure whether they are minute animals or minute plants. They ought to be plants, but whoever heard of plants able to absorb solid food?

Well, noctiluca do so, and other members of the peridinians, the group to which they belong; so, though they are usually classed as plants, nobody will quarrel with you if you choose to call them animals, for they are certainly on the borderline. Noctiluca is not alone in setting the seas on fire. There are other tiny organisms with this mysterious quality. Many of them are so exceedingly minute that a teaspoonful of water would contain thousands,[1] and it is hard indeed to realize the vast numbers in which they must exist. Yet it is known that they play a very important part in the economy of the seas; for along with diatoms and other diminutive floating algæ, they form the food material of the uncountable hosts of tiny animals—their fellow-travellers in the drifting *plankton*—that in their turn provide the staple diet of many of our most useful fish.

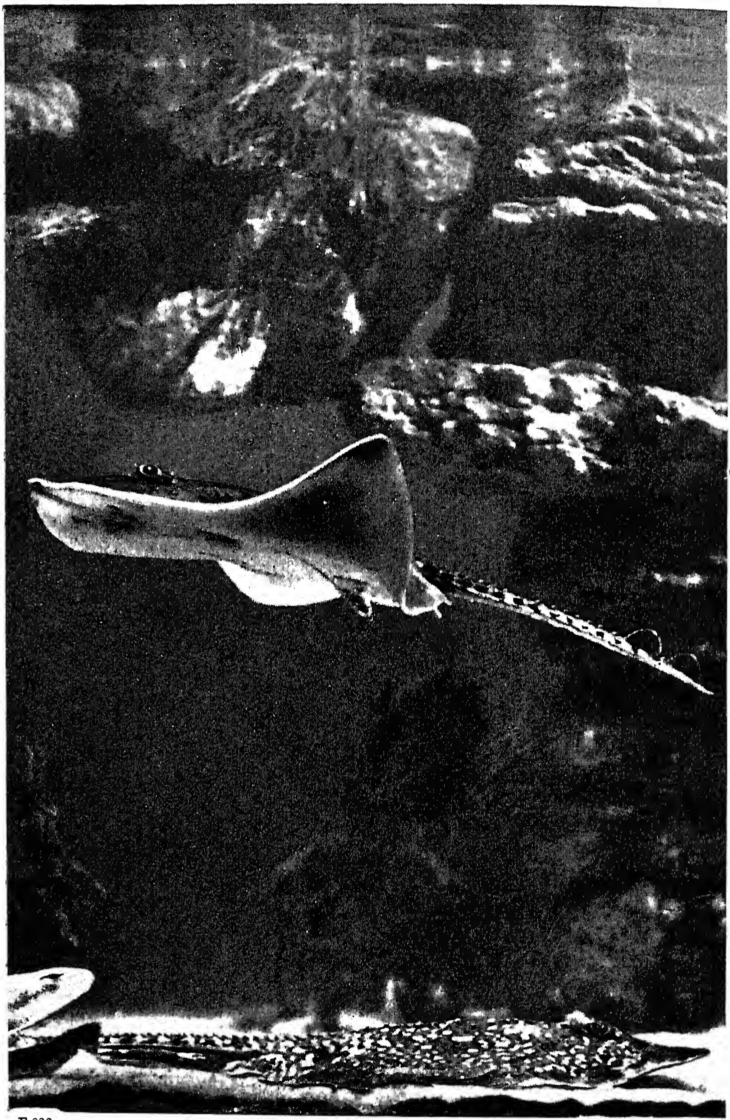
Very many sea-animals have the power of luminosity. Indeed, there is scarcely a group or a family that does not possess light-bearing representatives. Luminous jelly-fish sometimes appear off British coasts, but again it is necessary to seek in warmer waters for the most brilliant specimens. Sometimes the light comes from groups of light-producing cells arranged symmetrically about the animal's body; sometimes it issues from glands that secrete the luminous substance. But in the higher animals, and particularly in the fish inhabiting the greater depths of the seas, the light proceeds from wonderful organs called ocelli. These luminous organs are somewhat similar to eyes and are arranged in rows along the sides of many deep-sea fish. They are highly complex structures, with glands for secreting the luminous principle and lenses and reflectors, functioning just like an electric torch.

[1] Some of the microscopic organisms of luminosity, such as those that cause dead fish to glow, are as small as one twenty-five thousandth of an inch in diameter.

Naturalists are still doubtful about the purposes for which nature has provided these animals with lamps. It can't help them to hunt, and in any case we know that hunters and quarry alike seek to be as inconspicuous as possible, and not blazing like illuminated signs. Further, though many forms of deep-sea animals have very large eyes, in many others the organs of vision are either rudimentary or entirely absent. It is thought that the lights may serve in some kinds as a lure, in others as a warning, in others again as a guiding link between the sexes. While in the case of the lower animals that emit light not from the marvellous ocelli, but as a luminous secretion, the light may be an entirely accidental part of some other physiological function.

What makes the light? That question is more easily answered than, what use is the light? It has been known for a long time that the light is caused by the burning of two special substances called luciferin and luciferase, in combination with oxygen. Exactly what those two substances are made of has still to be discovered, but they can be treated in the laboratory like any other chemical compounds. The light produced is no different, physically, from any other light, but it is much better than any we can make, because the luminous animals have been taught to make it without waste of energy. We can't make light without making as well a great deal of unwanted heat. But this bio-luminescence is nearly 100 per cent visible radiant energy. In other words, it consists almost entirely of light rays, without the *invisible* ultra-violet and infra-red rays that always accompany our efforts at light making.

As they move through the cold inky depths, thousands of fathoms beneath the surface, the brightly lit abyssal fish must present a very weird and ghostly appearance. You may wonder how it is that any animals can live at a pressure of three tons to the square inch, the pressure of the



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SKATE SWIMMING

The skate at the bottom of the photograph is resting on its ventral surface. In the skate's swimming there is a wavy movement of the triangular fins, the undulation passing from the front backwards.

From a photograph by Neville Kingston

Facing page 197.

water on any object at a depth of 3000 fathoms, but you will see that so long as the internal pressure is the same as that outside the animal, the actual weight of the medium in which it dwells cannot make a great deal of difference. The abyssal fish do not much resemble their relations in shallower water. They are small as a rule, black or darkly coloured, and long in proportion to their girth. Their flesh is always very soft and watery, and sometimes nearly transparent. Owing to the difficulty of obtaining lime at great depths, their skeletons are very slender and fragile. They generally have huge, disproportionate mouths armed with formidable teeth.

One of the most interesting matters with which ocean science is at present very much concerned has to do with the distribution of the life in the sea. Sea-animals, and in a lesser degree sea-plants, are not confined to one plane as are the inhabitants of the land, which must perforce dwell on or about the surface. There is in the sea a vertical distribution of life as well as a horizontal one, and all levels from the surface to the profoundest depths are inhabited. Yet in the sea, as on land, the forms of life are very much restricted in distribution. We can't fish for the splendid tarpon in the Bristol Channel, though he could easily swim the Atlantic if he wanted to, and his humble relatives the herrings are not sought off the Gulf States of America, where the tarpon mostly dwells. The warm seas, again, are relatively poor in food fish, the cold northern seas extraordinarily rich. We have seen, too, that most of the great marine animal groups are represented at all levels, from the top of the sea to the bottom. There is a species of octopus that is sometimes a pest to the Scottish herring fisheries, and another octopus that lives at a depth of nearly two and a half miles, but these two octopuses could never meet. Each stays at the level assigned to it. There are

a few fish that change their levels, being able to secrete or absorb air or gas in their air-bladders, to suit the changed conditions of pressure, but they can only move up or down within narrow limits.

You can probably guess what is the main influence that keeps the different sorts of the higher animals so strictly to their separate zones and localities. It is food supply. And since their food is drawn very largely from the minute creatures that form the plankton, the life-histories of the animals and plants comprising this great category of sea life has become a very important subject of study. Plankton is not confined, remember, to the surface of the seas, but permeates the depths as far as they have yet been searched for it, some 2800 fathoms. The means by which the planktonic animals and plants are adapted for life at different levels are very wonderful. Some support themselves by bubbles of air or gas, some secrete globules of fat. There are others that prevent themselves from sinking by alterations of shape, they flatten out their bodies to increase their resistance to the water; and some kinds grow long spines for the same purpose. But whatever their kinds, and wherever they may be found, there seems to be one influence directing their distribution that is more urgent than any other. This influence is temperature, which, we have seen, varies from sea to sea and from level to level. We have seen, too, in other chapters, how the changes of temperature are a part of the ocean's response to the universal rhythms that create the currents in the air and in the waters; that bring us the seasons, the monsoons, the ice drifting down from the Poles. Interwoven with these rhythms are periodical changes in the lives of the sea-creatures, regular pulsations that make most fascinating study. These animal rhythms are being gradually made clearer by eager workers, but there is still much to be learnt. Can you wonder they are eager?

CHAPTER XV

Fishing and Fisheries

Only a very little of the teeming life of the sea—a mere infinitesimal fraction of the whole—is made use of by man, though no doubt much more of it could be used, but for difficulties of transport and marketing. Be that as it may, coastal waters have been made to yield their harvest of edible fish for ages that cannot be measured. The fishers gradually went farther afield, driven by competition and increasing demand, learning as they went more and more of the habits of the finny tribes, and now the seasonal changes that influence the movements of fish are in many cases as well understood as the circling seasons on land.

The men of Brixham and Barking dispute for the honour of having been the earliest deep-sea fishermen: certain it is, that the fisheries of Grimsby and Lowestoft were built up by Brixham men who left their own bays and fishing-grounds and, sailing up the Channel, entered the North Sea and discovered its fertility. Those were the days of line-fishing, a method which now persists only on a very small scale. Though the fish caught by lines is said to be "livelier" and of much finer quality than that brought up wholesale by the trawls, the operation is so slow that the linesman cannot compete with the trawler. A "liner" goes to his ground in the evening—often ten or fifteen miles from his home—anchors his boat and drops his line. Generally three men share the boat and each works two

lines. At the end of the night, perhaps, they have caught between them eighteen dozen whiting, varied by pollack and skate; if luck has been very good perhaps a turbot, or a troublesome six feet of conger eel. It is anxious work in a swell, uncomfortable work at all times, and there is hardly a living in it. When the beam-trawl was introduced the liners found their harvest seriously curtailed; then when the otter-trawls came, the beam-trawlers complained, but in actual practice there is so much variation in the habits of different fish that each method may be sure of some success. Lines, for instance, can be used over rocky bottoms that would spell ruin and destruction to trawls.

The trawl is, of course, a large net, conical in shape, which is "shot", that is, let down from the side of the trawler and dragged along the sea-bottom, scooping up the fish, demersal fish as they are called, which live there. The net is provided with valves known as "flappers" or "pockets" which prevent the captured fish from swimming to the mouth of the net and escaping. The under side of the net is protected by layers of old netting. In the case of the beam-trawl, the mouth of the net is kept open by iron runners called "shoes" which carry between them the forty- to fifty-foot beam. The upper edge of the net is attached to the beam, and as the shoes may be three feet or more in height, a full-sized net will have an opening of fifty feet by three, and the net may be a hundred feet in length. Such huge nets are very difficult to manipulate, d require great skill in shooting and hauling in. The trawl is towed by means of two strong ropes, called bridles, attached to the runners, the bridles being joined to a steel hawser which passes through a fair-lead in the trawler's bulwarks to the winch or capstan that hauls it in.

As you may suppose, the beam-trawl scoops up the flat fish—plaice, dab, sole, halibut, turbot or brill—which

haunt the bottom; but its opening, restricted as it is by the height of the runners, is so small that it passes *under* the haunts of most "round" fish, whose habit it is to swim several feet above the bottom. The otter-trawl is a form of net which, because it has a much larger vertical opening, enables trawlers to catch a greater variety of fish. If you really wish to understand how the otter-trawl works, take a run round the garden, holding in each hand a kite made by attaching a piece of cardboard by its centre to a length of string. If you have ever flown a kite you will know without this experiment (which might make you rather conspicuous) what happens when you run. As the air-resistance increases, the squares of cardboard move outward, and thus get farther and farther apart.

"Kites" of the same kind are used to hold open the mouth of the otter-trawl. The beam—at best a clumsy contrivance—is, of course, dispensed with; and at each side of the opening of the net is a wooden oblong "door" or "otter" up to nine feet long by five feet high. The ropes which pass along the top and the bottom of the net—the head-rope and foot-rope, respectively—are fixed to the hinder ends of the otters; and the bridles of the towing-rope are attached to the otters in such a way that, the point of attachment being slightly behind their centres, the otters "sheer away" when the net is towed, one moving to starboard and the other to port. Instead of the width of the net being arbitrarily fixed by the length of the beam used to extend the beam-trawl, in the otter-trawl there is no limit except that imposed by convenience and ease of handling. But a more important advantage is the increased height of the mouth of the net. The head-rope is buoyed up by floats, and the front edge of the net is thus raised into the form of an arch.

By one or other of these forms of trawling, fishing for

cod, halibut, haddock, plaice, sole, skate, and some other species, is carried on year after year in the inexhaustible waters of the North Sea, the English Channel, the Irish Sea, and the Atlantic Ocean as far north as Iceland. Steam trawling vessels well packed with ice do not mind how far from home they go, even to the White Sea or to the warm shores off Morocco. Away they go with nets, winding-gear, and ice, anywhere they can find a bottom free of rocks no deeper than two hundred fathoms. In favourable weather they even let their trawls down on the Continental Slope of the Atlantic to as great a depth as five hundred fathoms, gathering up the hake which abound there, though why anybody should want to eat hake will always be to me one of life's unexplained mysteries.

And what of that " bonny fish and halesome farin' "—the herring, that brings subsistence to millions of poor folk who seldom taste butcher's meat or dairy butter? The herring fishery is a complete industry in itself, of great commercial importance to this country and vital to the dwellers on the bleak coasts of the north. The old idea of the herring was that in spring and summer vast bodies of the fish moved southwards, having spent the winter in the Arctic circle. But that is now known to be wrong, and in reality the herring does not travel any great distance from its spawning-ground. Apart from this false idea, a description of the herring shoals given by a zoologist more than a century ago, is well worth repeating:

" This mighty army begins to put itself in motion in the spring; we distinguish this vast body by that name, for the word herring is derived from the German *Herr*, an army, to express their numbers.

" They begin to appear off the Shetland Isles in April and May; these are only the forerunners of the grand shoal which comes in June, and their appearance is marked

by certain signs, by the number of birds, such as gannets and others, which follow to prey upon them; but when the main body approaches, its breadth and depth is such as to alter the very appearance of the ocean. It is divided into distinct columns of five or six miles in length and three or four in breadth, and they drive the water before them with a kind of rippling; sometimes they sink for the space of ten or fifteen minutes; then rise again to the surface, and in bright weather they reflect a variety of splendid colours, like a field of the most precious gems, in which, or rather in a much more valuable light, should this stupendous gift of Providence be considered by the inhabitants of the British Isles."[1]

We know now that the old zoologists were misled by the later season of spawning in warmer waters into believing that the herring shoals actually travelled. It is not one of the least remarkable features of the herring, considered as a public benefactor, that the fishing season is so long. Beginning as it does in the north early in the summer, the fishers, the packers, and curers follow the season southwards, and thus find highly profitable occupation from May to October. There is more than one species of herring, and the different species spawn at different times; and as they all congregate together at the breeding-season and return year after year to the same breeding-grounds, their appearance can be foretold with perfect accuracy. In the same way the mackerel, pilchard, sprat, and anchovy, all of which are pelagic fish, that is to say, they do not live on the bottom, but swim rapidly about at a medium depth, or near the surface, all assemble in tremendous shoals to breed, and thus are caught in great numbers at such times.

The herring provides the material, not of one industry merely, but a whole chain of industries. First, the catching

[1] Pennant: *British Zoology*, 1812.

of this fish is a livelihood in itself. The herring, apart from its commendable virtue of occurring in such vast numbers and providing a rarely-equalled food, crowns its list of good qualities by lending itself most admirably to curing. The red herring, a salted and dried product, will keep for many months and in that form is exported in great quantity not only to neighbouring countries, but to the great Roman Catholic countries farther afield, where fish is much in demand for fast days. The kipper and the bloater, being more lightly salted and smoked, do not keep very long, but retain the oiliness of the fresh herring to much greater extent and thus make a welcome and nourishing addition to the breakfast table. The curing of the herring is carried out by crews of Scottish women and girls, who travel down the coast in the wake of the herring shoals, stopping at all the important fishing centres as long as the season lasts.

In a very delightful book, Moray McLaren's *Return to Scotland*, there is a vivid word-picture of an expedition in a herring-boat. The writer, who was making a pilgrimage through the Western Highlands, paid a visit to the island of Barra, where he made friends with some fishermen. He says:

"Until the hauling in of the nets there is little that is eventful in the herring fishing. We set sail at nine o'clock, and cruised up northwards, sheltered from the Atlantic swell by the string of islands which we kept always on the west of us. At twelve we began to lower away the nets until nearly a third of a mile of them were stretched out, floating with the tide. They were supported every twenty yards or so by a float; and when we came to the end of them we tied the last rope to our windlass, and the fishermen went down into the cabin—to drift about for a couple of hours, waiting for the nets to fill with the shoals of herring

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CUTTLEFISH

From a photograph by F. Martin Duncan, F.R.M.S., F.Z.S.

Facing page 204.

which were rumoured to be cruising about this evening. . . . About two o'clock, that is to say, just when the dawn was beginning, my companions came out of the cabin and we all stood to, to help with the pulling in of the nets. We were set to separate and definite jobs; two men worked the pulley which hauled in the nets; another arranged the floats; another carefully but swiftly folded back the nets when they were finished with; to me and to a boy—the son of one of the fishermen—there fell the task of shaking and combing out the fish from the nets, and flinging them back into the hold. I have seldom seen anything which was quite so physically and coldly lovely. For the first fifty yards or so of the nets we found nothing; then quite suddenly we began to pull on board over the tiny boat, sheets and sheets of shimmeringly ecstatic silver. My back was soon aching and my hands and arms up to the elbows slimy and wet with fishy blood, torn and bruised with the net. But throughout the long two hours which it took to haul in the net, I was never tired of watching the harvest. The herrings flopped, shivered, gleamed, and died as I piled them into the hold; but innumerable thousands more emerged from the black and moving sea. It seemed to me endless, but it was lovely."

Pelagic fish like the swiftly swimming herring and mackerel, cannot be caught in a trawl, but the fisherman makes use of their anatomy to catch them in a drift-net. The net, the size of which depends simply on the capacity of the boat which is to carry it and its catch—in the case of a big boat there may be a train of nets three miles in extent—is shot over the side of the boat and allowed to drift with the tide, the upper edge being attached to floats. There is thus made a wall of nets. In their headlong rush the fish composing the shoal drive full-tilt into the meshes, where the opening of the gills, or the first dorsal fin, keeps

them fast. The number of herring caught annually is colossal; in 1924 it was estimated that the fisheries of northern and western Europe had landed 7,500,000,000! In that year the value landed in England alone equalled £4,500,000.

Fishing with a drift-net is carried on at night time in order that the fish may not see the net. Sardines, which are simply young pilchards, are caught in the twilight, either of dawn or sunset, and the net used for catching them is dyed a bluish green to make it merge into the colour of the water. Mackerel are caught off the Scilly Isles in spring and early summer, their season preceding that of the pilchards. From November to February the sprat holds the most important place in the fisheries of the east coast, Aldeburgh in Suffolk being the metropolis of the sprat industries; while at the same period of the year white-bait are caught in large quantities in the Thames estuary and in the Wash.

The pilchard fishing of Cornwall and South Devon, is performed from small boats. At the pilchard season you may find the men in their boats with nets and gear ready, lying off shore. Climb the cliffs above them and sooner or later you will come upon a man armed with a large branch of gorse. He does not turn his head as you approach; his gaze is rivetted on the water below. Standing beside him you are suddenly startled beyond measure by seeing him jump to his feet and wave his gorse branch violently, pointing in one direction, accompanying his action with wild cries. As if by magic, the motionless boats leap for the open sea. The man on the cliffs is the " Huer " and he has seen the ripple in the water which signifies the pilchard shoal.

Although British waters provide a very large number of edible fish, some of the continental countries, though

lacking the sorts we enjoy, specialize in particular kinds. Thus, French sardines are most in demand, and the herring's little relative, the anchovy, is only of importance in the Mediterranean. The Danes are the greatest authorities on plaice and eels—a curious combination of two very curious fish. The North Sea off Denmark is particularly rich in plaice and so valuable are these fish as a food supply, that the Danes have brought to success a method of transporting them from the open sea to inland salt-water reservoirs. The eel, too, is most carefully cultivated by them, and it is to the investigations of Danes that we owe most of what we yet know of the life-history of this strange fish.

The idea of fishery research, to be conducted on scientific lines, was first stimulated by the suggestion that trawling would destroy the eggs of fish. If this were so, it followed, as a logical conclusion, that ultimately all fish might become extinct! To discover how far this suggestion was plausible, an expedition was sent out in 1864 under the guidance of Professor Sars. The first result of its efforts was the finding of large numbers of pelagic eggs; that is to say, eggs drifting in the body of the water considerably above the bottom. But what were the eggs? There was only one way to discover, and that was by hatching them artificially, and when that was done a nursery of young cod appeared. This discovery was a very important addition to our knowledge of the life-histories of fish, and other eggs were treated in the same way until at last it was established that the eggs of all the economic fish are pelagic—with one exception. That exception is the herring—pelagic itself—which lays its eggs in crevices of the rocky bottom, where they are safely out of the way of the trawler.

The distribution of the fish we eat is very local. To the careless or ignorant mind, one piece of sea is very much like another. But we have seen that there are subtle variations

of temperature, and the fishy people have very strongly developed requirements which may be satisfied in one area, but not in another only a few miles distant. First and foremost they are concerned with food supply, and science is beginning to understand why it is that one patch of the North Sea will nourish the particular form of life required by the sole, and another will not. Anyhow, the sole knows enough about it to thrive in the area between East Anglia and Holland, rarely venturing north of Yarmouth. He also likes the sea south of Cornwall, and west of the Bristol Channel, and he is to be found off the coast of Spain. It is this daintiness of his which makes him scarce and expensive, whereas the plaice swarms happily from the coasts of Iceland right down and across the North Sea and the English Channel. He does not visit our western shores to any extent, except in the southern waters of the Irish Sea. Turbot is a rare fellow, and the English shores do not attract him very much. But he is found in the English Channel; and his great size and value are such that the catching of one turbot often repays a linesman for a night of otherwise unprofitable toil. The cold seas northwards yield cod, haddock, halibut, ling, coal-fish, and cat-fish. Skate does not venture much north of the Orkneys.

I have coupled almost in the same breath fish that differ in a most astonishing way, not in habit only, but still more in appearance. If the cod, as a "round" fish, is regarded as the typical fish form—the form associated in our minds as proper to most fish—what can we think of the skate? It looks rather as though it had been flattened in some strange accident! You may not often see a skate, perhaps, although a good deal comes to market, because most of it goes to restaurants and fried-fish shops. Its appearance is so forbidding that the fishmonger has little chance of selling it until it has been cut up into unrecog-

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THE "CATCH"

The net of a North Sea Trawler being hoisted aboard.
The cod-end of the net is seen.

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nizable pieces. The flesh on the broad, expanded, pectoral fins is very good indeed. If you ever have a chance to look at a skate (it is the same fish as the ray) you will notice that it has been flattened from above, all but the tail, which seems to have escaped the accident. Now compare it with the more characteristic flat-fish—sole, brill, turbot, flounder, or plaice. There's not much resemblance, except in flatness, and the plaice looks even more unorthodox, though less ugly, than the skate. The latter may have been trodden on by an elephant, but the plaice seems to have been under a steam-roller.

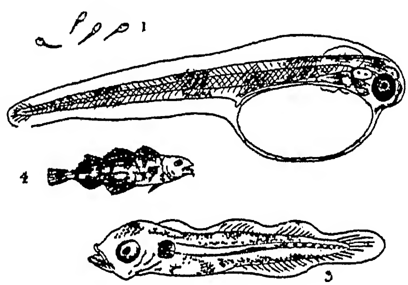
These two very different kinds of flat-fish which live on the bottom are excellent examples of the natural law that insists that organisms must be able to adapt themselves in order to survive. The skate is a powerful, voracious animal, but sluggish in its movements, living largely upon shell-fish, which are also the food of the true flat-fish; but whereas he swims or rests stomach downwards in the usual way, and has his eyes one on each side of his head, the plaice and the turbot and their relations are very differently arranged. They swim on their sides and have both their eyes on the same side of the head, pointing upwards. It would seem that the skate tribe, having once learnt to adopt the form best suited to their needs, asked no further teaching. Flop, flopping over the sea-bottom, they go, with gentle undulations of the great breast fins; and flop, flopping go the plaice and the flounders—but with what a difference! For *they* use their back and stomach fins, and have turned over on their sides to do so.

To get a clear idea of what has happened to them, imagine an ordinary fish—a cod or a whiting—squeezed right way up in a vice, so that his lateral thickness is much diminished and his vertical thickness much increased. Imagine him now put back in the water, and turning over on his side

to swim. The strangest thing is that he hasn't learnt how to be flat once and for all, as the skate has, but needs teaching with each generation. For a little while after they are hatched, baby plaice and all other flat-fish are not much unlike the young of most fish. They are symmetrical and have their eyes in the normal positions, and they swim about freely in the sea. After a few weeks, the tiny creatures feel a hankering for the delights of the nice soft bottoms of mud or sand, with plenty of suitable shell-fish, on which they can live lazily with little fear of observation from the great greedy beasts around them. So down to the bottom they go, and there they begin to lean over to their left sides. More and more they lean over as the days go by, and while their lower sides, half buried in the soft bottom, remain white, the upper sides become coloured until they exactly match the material of the bottom. Meanwhile the back and belly fins are growing very large, to take the place of the useless pectoral fins. The baby fish is now nearly adapted for its new mode of life, but not quite; for one eye, that on the left or under side, is gazing uselessly into the silt, at uncomfortably close quarters. To complete the transformation, therefore, the left eye begins to travel round the head. A twisting of the bones of the face shifts the eye right across the top of the head until it lies beside the other eye, and the tiny flat-fish can henceforth make proper use of both. The whole process takes about a fortnight.

Like most fish, the cod starts life as an extremely small individual. His mother may have laid as many as five million eggs, so that allowing for all probable casualties, and fish eggs form a staple diet of adult fish, he is one of a large family, so large that it is not to be expected that the parents can take any interest in it. Therefore the young fish has to fend for himself from the very beginning, and

after he has finished up all that remained of his egg, after about three days of fishy existence, that is, he has to find food for himself. Being very small, however, he is exposed to innumerable enemies against which instinct warns him to find some protection. He makes the most of all forms of shelter, one of which is particularly curious but so effectual as to be made use of by many species of young fish. It is the large blue jelly-fish (*Cyanea*) which is to be found in abundance at the time of year when young fish are most prevalent. This jelly-fish is of a very virulent nature. But it is obliging enough, from a fish's point of view, to grow very large, sometimes, indeed, attaining a diameter of six or seven feet, with immensely long tentacles. Beneath the shadow of this formidable floating umbrella, myriads of baby fish seek shelter when danger threatens. Quite inexplicably, the jelly-fish—surely the most unemotional of all created things—makes no attempt to destroy its trusting little guests.



1. Codlings just out of Egg ($\frac{1}{10}$ in. long).
2. Same magnified showing yolk sac.
3. Later stage: yolk sac absorbed (magnified).
4. Perfect young cod.

Having passed safely through its early months, we can imagine our cod grown to maturity and joining with his kind in the great gathering of the species which takes place at spawning time between the months of January and May. With incalculable thousands he has journeyed to the Grand Banks of Newfoundland, or to the coastal waters of Sweden, Iceland, or the north of Scotland. Anyone who has read Kipling's *Captains Courageous* will remember the vivid

story of the Banks' fishermen, but that book was written many years ago and the cod fishery is now practised on a much larger scale. In the story, you remember, the men used to leave the schooner in dories and drop out the baited hand-lines—two hooks to each line—coming back when their catch was complete. Nowadays, hand-lines are superseded by what are called "long-lines". These are of quite extraordinary length—forty or fifty fathoms—each carrying eighty or ninety baited hooks. The fishing is still done from dories, mere cockle-shells which work in fleets, each little fleet being attended by a larger "mother" boat, usually a schooner. Each dory carries between thirty and forty lines, and is thus responsible for the baiting of several thousand hooks. And as the lines are often joined together, a single dory's line trails out for a couple of miles or more. When the dories return to the ship the fish are split, cleaned, and packed in salt. Dried and salted cod is taken in large quantities from Newfoundland to the West Indies and to the Roman Catholic countries in the south of Europe.

In this short chapter it is obviously quite impossible to do more than mention a few of the commonest of the edible fish of Britain. We cannot, for instance, travel afar to watch the Chinaman fishing with trained cormorants, or the Indian of Central America standing up in his canoe with arrow fixed and bowstring taut, ready to shoot his fish when it appears; nor even the Eskimos fishing through a carefully made hole in the ice. But I think we ought to spend a few moments in the study of that most peculiar and perplexing creature, the eel. I am half hoping that there may be someone ready to retort, "The eel is a fresh-water fish!" and so, indeed, he is generally reckoned, since it is in fresh water that we catch him for eating, but he comes to us from the sea. Not so very long ago, the origin of eels was still wrapped in mystery and superstition.

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WHALING

Harpoon-gunners in a whale-chase ready to fire but waiting for the whale (as yet too close to the bows) to move 20 or 30 yards away. Photographed in the vicinity of South Georgia.

Facing page 213.

It is not surprising, perhaps, that when it was believed that the sun's rays falling upon the mud left by the receding waters of the Nile could cause the spontaneous generation of rats and mice, it was also believed, according to Izaac Walton, "that as pearls are made of glutinous dewdrops, which are condensed by the sun's heat in those countries, so eels are bred of a particular dew, falling in the months of May and June on the banks of some particular ponds and rivers . . . which in a few days are, by the sun's heat turned into eels." The mystery lay in the fact that eels were found almost everywhere in ponds, streams, or rivers, but always fully formed, never in a very young stage. Nobody had ever seen an eel's egg. On one day a pond might appear empty, and on the next, a small eel might be seen in it. Where had it come from? Of course, many hypotheses were put forward, not all of them as wild as that cited by Izaac, but in 1922 the completion of the studies of the great Danish oceanographer, Dr. J. Schmidt, settled the matter once and for all.

During his researches in the Atlantic Dr. Schmidt found, in the region of the Sargasso Sea, some curious little creatures to which the name *Leptocephalus* was given. These little fish were upwards of a quarter of an inch in length, flattened and leaf-like, and quite transparent. As his work progressed, Dr. Schmidt found more and more of these creatures, and a curious fact presented itself, namely, that the nearer he approached the European shores the larger did these fish become. Convinced that he was following out a new discovery, Dr. Schmidt pursued *Leptocephalus* with all his energy, measuring and comparing until, by the time his ship had regained the Danish shore, Nature had unfolded her riddle to the man who had the perseverance to solve it. *Leptocephalus* was an eel! The fish-like appearance had gradually altered, the creature becoming shorter and

rounder until it was unmistakably an " elver ", as young eels are called.

Thus the whole life-history of the eel has been unravelled. The elver, on reaching European shores, enters into fresh-water rivers, and makes its way inland. From big river to small, from small river to stream, it swims into the heart of the country. When occasion offers, it cheerfully leaves its river and wriggles overland, having been provided with gills capable of retaining moisture for this express purpose, and in this way it is able to appear in land-locked ponds or water-holes. Throughout its journey and for the rest of its fresh-water life, it eats vast quantities of fish and thus is hated by fishermen and river conservators, but all the time it is growing, growing. Then suddenly, some day, —it may not be for fifteen or twenty years,—the eel feels a new impulse. Its colour changes from black to silver and, willy-nilly, it starts off for the sea. Out of the pond and over the meadows to the stream, down stream to little river, on and on into big river, away and out to sea—so it is led by this strange instinct. The eel, poor, stupid thing, has no notion of where it is going, nor why, but the fact is that it swims and swims, right across the Atlantic, until it reaches the Sargasso Sea. There it spawns, and having spawned (the female sometimes lays over 10,000,000 eggs) it dies. The eggs hatch and become the little sharp-snouted creatures called *Leptocephalus*, which work their tiny way back through the Atlantic, a journey which takes them three years, to the fresh-waters of land. Surely there is no story of nature more strange and wonderful than this!

CHAPTER XVI

Leviathan and his Relations

Thirty years ago few stories of adventure were so generally popular as stories of whaling expeditions. Great clumsy fellow that the whale is, whatever his species, the courage and cunning of man in capturing him from a cockle-shell of a boat is always a matter for amazement. His haunts and habits, his comings and goings, all are, to the landsman, wrapped in mystery. Much of that mystery has now been dispelled in the light of modern oceanographical knowledge; unfortunately, also, the prolonged slaughter of the whale has made him a rarer trophy.

Your encyclopædia will tell you that whales belong to the order of mammals called Cetacea, which is sub-divided into Mystacoceti or Balænoides (whalebone whales), Odontoceti or Delphinoidea (toothed whales), and Archæoceti or extinct Zeuglodonts, with which we have nothing to do at the moment.

Of the baleen whales there are five distinct kinds; the Right Whale, northern and southern varieties; the Rorqual; the Humpback; the Pigmy Whale of the Australian Seas; and the Grey Whale of the North Pacific. Many other varieties belong to the toothed whales, the most important being the Cachalot or Sperm Whale, while other members of this great family are the dolphins and porpoises, the Arctic Narwhal, the Beluga, the Killer, Caaing, and Bottle-nosed Whales, and the smaller forms which penetrate into fresh-water rivers. Few of us ever have the chance to see a

whale, but those fortunate enough to take an ocean voyage may do so, and occasionally it happens that a whale is stranded on the seashore, and therefore a short description of the different kinds with a view to identification may be of some use.

In general outline, of course, the whale is familiar enough. Zoologists are still undecided whether he has evolved by force of circumstances from an immense land mammal, or whether he has always lived in the sea, but it seems certain that in the process of evolution he has lost all but the most rudimentary remains of pelvis and hind-legs. His arms, or front legs, have become fins, the arm bone being short and broad and the finger joints being bound up with sinew. Every other mammal in the world, not even excepting the duck-billed platypus, has the same number of joints in its fingers and toes as the human family, but the " fingers " of the whale, all skinned across to make a useful fin, have many more joints, in some species as many as twenty. The fins are not used for swimming, but as balancers, the swimming being done by the huge forked tail. The hairy coat which the land mammal may have worn, has vanished, since matted wool would be a most uncomfortable garment for the sea, and the whale now wears its protective covering *under* the skin, in the shape of the layer of blubber which constitutes its chief commercial value.

In form the whale is built for convenience in travelling at a good speed, having its greatest bulk in its head and shoulders, from which it tapers away. The Right Whales, and in fact all baleen whales, have double nostrils, whereas sperm whales have only one. The Right Whales carry whalebone in great length, and their heads are proportionately much larger than the heads of Rorquals and Humpbacks, in which the whalebone is shorter. The Humpback has

a distinctive feature in its immense white flipper. The Arctic Narwhal is remarkable for its formidable horn, which is the only tooth this so-called toothed whale possesses, and only the males of the species have it, at that. Do you remember that Captain Nemo's submarine was believed to be a giant Narwhal, and that Ned Land, the harpooner, was confident of his ability to destroy the monster? You do not, and you never heard of Captain Nemo? Then let me recommend you to read Jules Verne's *Twenty Thousand Leagues under the Sea.*

But to return to our toothed whales. The Beluga is a pure white whale of the Arctic, that sometimes visits the coasts of Scotland. All the toothed whales may attack, but the fiercest and most deadly of all is the Killer Whale or Grampus. It is not very large, fully grown males averaging only thirty feet in length. But it is conspicuous on account of the high curved fin on its back, and also by reason of the yellowish-white stripes on its body. Its weapons are a dozen teeth in each jaw, whereas the other forms of toothed whales have teeth only in the lower jaw. The Caaing Whale—a dolphin—is not of great economic importance, but it sometimes comes inshore on the coasts of the Orkney and Faroe Islands, when the inhabitants surround the herd in all the available boats, and " ca' ", i.e. drive them on to the beach. Once high and dry they are killed without much difficulty. The Bottle-nose, with three others, belongs to a small class known as Ziphioids or Beaked whales—from the Greek *Xiphos*, a sword. In this whale the head lengthens out into a snout. As to the common porpoises, which we so often see leaping and frolicing in the water a short distance from land, and the common dolphin, these animals are so similar that you are not likely to be able to distinguish between them, since the chief difference is that dolphins have pointed, and porpoises flattened,

teeth. They are not likely to stop their games to grin at you, and unless you examine a dead specimen I don't think you will ever have a good look at the teeth of either of these creatures.

Whale hunting has been the sport of adventurous spirits for many hundreds of years, in fact it is impossible to say for how long the Japanese, Eskimos, Indians, and Tartars have successfully hunted the whale. The daring and resourceful Norsemen, of course, were mighty whalers, but from the ninth century a famous race of whale fishers existed in the Basque provinces, to the ultimate destruction of the Biscayan whale. The word harpoon is said to be of Basque origin. Their efforts drove the whales northwards, and so the centre of the whaling industry shifted, and in the sixteenth and seventeenth centuries the Dutch had a flourishing station on Spitzbergen. When the whales had drawn away from that region the Dutch followed them to Greenland, but within a hundred years the Dutch whale fishing declined altogether and the British came to the fore. British enterprise, however, was soon outdistanced by American, and during the hundred years from 1750 to 1850, American whaling vessels ventured from Newfoundland to Brazil. But the boom was over. Since 1850 the whaling industry in all northern seas has diminished, and the Peterhead and Dundee vessels which used to bring home record catches, not infrequently make entirely profitless voyages. Meanwhile, the riches of the Antarctic are paying toll, and the whaling stations of South Georgia are reaping large harvests; in fact, so great is the slaughter in those waters, that there seems a serious danger of the extermination of the whales.

In the season 1925–6 no fewer than 13,188 whales were taken in the dependencies of the Falkland Isles, producing 722,500 barrels of oil. All but a small proportion of the

whales belonged to two species of Rorquals. Presumably, history will repeat itself and the whales will move on to other seas, "until this tyranny be overpast". The best means by which whales may be saved from extinction is a problem at last receiving the attention it ought to have had years and years ago. The big commercial firms engaged in the whaling industry, in which much capital has been invested, are seriously concerned for their future—so much so that they found most of the money for the *Discovery* expedition—a very ambitious scheme of investigation. Several years' systematic study by this expedition, which was nominally undertaken by the Government of the Falkland Islands, has brought forth much new knowledge of the lives and habits of whales. In a little more than two years the *Discovery* staff had examined nearly 1700 whales—to give you an idea of how hard they must have worked! But the poor whale needs more than investigation—valuable as that must always be. The interested countries must bring to him some useful form of protection, and to this end the very important body known as the International Council for the Exploration of the Sea, is now earnestly working and is seeking the co-operation of the League of Nations.

The Right Whale, which carries the greatest amount of whalebone, has, as previously stated, an enormous head. Its total length may be over sixty feet, of which the jaws extend to twenty feet. When the whale is hungry, which must be nearly always, it opens its vast mouth, and the whalebone—or baleen, to give it its technical name—hangs from the upper jaw in a series of plates fringed at the edges. This horny screen is continued across the back of the throat and thus forms a semi-ellipse facing the mouth. The whale, swimming into a colony of the tiny forms of life on which it feeds, mostly small crustaceans, takes a mouthful, closes

its jaws, thus squeezing out the water, which trickles away at the sides of the mouth, leaving the solid food caught in the fringes of the balleen. The action of closing the jaws folds down the baleen with the fringe pointing towards the throat, and down go all the little crustaceans in one vast swallow. In a large Right Whale the baleen attains a length of ten or twelve feet at the back of the throat.

Several different kinds of Right Whale are recognized, including the Greenland whale—which is regarded as the true polar whale and keeps principally to Arctic waters—and the Biscayan whale or Nordkaper, a great traveller whose journeys seem to extend from Spitzbergen to the Azores, and also to the Mediterranean. It is not definitely established that the *Balæna Australis*, or Southern Right Whale, is a distinct species rather than a branch of the Biscayan family. This whale has much shorter baleen than the Greenland whale. Still another Right Whale is found in the northern waters of the Pacific Ocean, known as *Balæna japonica*. This is the whale which the Japanese hunted more than a thousand years ago, and in spite of constant and unremitting persecution it still persists in haunting the same waters. The Greenland whale, on the other hand, is diminishing in numbers, and seems to have embarked on the downward path leading to extinction.

The Rorquals are very large whales but have comparatively small heads and consequently no great length of whalebone. On this account they have not been hunted with any assiduity in the past, and therefore their numbers increased greatly in proportion to those of other families. This is the whale we may sometimes see stranded on the beach, with the skin under the throat deeply furrowed as though it had been combed when molten and the comb marks had set. The Rorqual is now regarded as a very valuable animal, and is keenly hunted. Supplies of

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A WEDDELL SEAL ABOUT TO DIVE

From a photograph by Herbert G. Ponting

Facing page 220.

nourishing meat and meat extract are obtained from the flesh, the bones are used as manure, while a high proportion of edible fat is taken from the oil.

The rise of the Rorqual to commercial importance is due to the enterprise of a Norwegian named Svend Foyn, who, towards the end of last century started to fish for Rorquals, finding that although their yield of whalebone was small, they possessed oil in great quantities, and it was he who put the flesh on the market as " whale beef ". But his name must always be remembered as that of the inventor—or more correctly the rediscoverer—of the harpoon gun. Actually, a gun for the expulsion of the harpoon was used by two Irishmen in 1760, when the harpoon was fired from a swivel gun; but by Svend Foyn's time the explosive bullet had come into being and this was the factor which made his harpoon gun such a success.

The average length of Rorquals is sixty to seventy feet and their strength and speed are prodigious. Having less baleen, they are able to tackle larger foodstuffs than the Right Whales, and enjoy fish as big as herrings and pilchards, but, not liking to be gluttonous, they collect their mouthful in an expanding pouch in the throat. When the pouch is full, they swallow the contents at one gulp. Sibbald's Rorqual, sometimes called the Blue Rorqual, is the giant of all the whales, and in fact of all existing animal life. Specimens are often ninety feet long and of unbelievable bulk, weighing about 400 tons. There can be little wonder that Rorquals used to be treated with discretion before the advent of explosives to help in their capture. A distinction of the Rorqual family is that its members do not, in diving, plunge head downwards with a lash of the mighty tail, as do the Right Whales, but sink gradually. The Humpback, a lesser relation of the Rorqual, is another far-seeking whale, and is believed to make annual migrations from

the northern hemisphere to the southern and back again. Certainly it crosses the Atlantic, as Humpbacks carrying American harpoons embedded in their flesh have been caught on European coasts.

Not less interesting than the baleen whales are the toothed whales. The Sperm Whale or Cachalot is another big fellow, sixty to eighty feet long, and his head is enormous, but not for the purpose of carrying baleen. He bites his food with his single row of teeth, instead of sieving it, but his head is large because inside it he makes the valuable spermaceti from which he gets his name. This, when treated in the factory, produces the very finest wax for candles and ointments. The disproportionate head so outweighs the rest of the body that the Cachalot has to turn on its back, like a shark, to feed. The oil of this whale is of very fine quality, and occasionally a still more valuable product is found in the shape of ambergris. This is a puzzling substance secreted in the intestines of the Cachalot. As it is frequently found together with portions of cuttle-fish (the Cachalot's favourite food) it is thought to be composed of some result of digested cuttle-fish. Perfumers are prepared to pay a preposterous price for it, for like musk and civet, though of disgusting odour itself, it is an admirable vehicle for the retention of fine scents.

The Beaked Whales also dine on cuttle-fish, in fact the student of the cuttle-fish has to rely largely on examples found within slaughtered Sperm and Beaked Whales for his knowledge of some of the rarer forms. The whale, thanks to his protective coating of blubber, is capable of diving to the fearsome depths of the ocean where the largest cuttle-fishes have their happy homes. It is said that a whale after taking a good breath of air at the surface can dive perpendicularly to a depth of 5000 feet. Presumably when there he eats a cuttle-fish or two, then rises to the

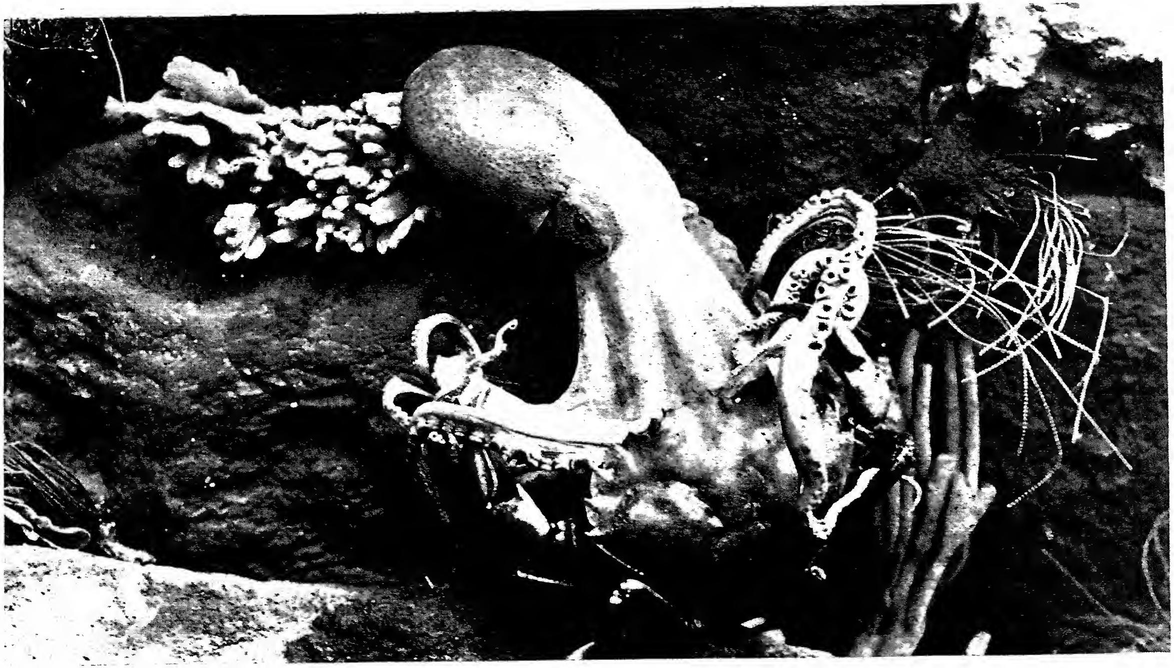
top again, where once more his blubber saves his life, this time preventing him from bursting like a bubble. But it does not save him from the harpoons and lance of the whaler, who hauls him ashore in triumph, cuts him open and discloses to the interested eye arms of cuttle-fish, perhaps six feet long by eight in circumference, brought to the surface in perfect condition by this animated drift bottle.

Sperm Whales are not often caught at the Scottish whaling stations, and any that may be caught prove to be young males. This seems at first sight rather a remarkable thing, but the males so caught are wanderers who have been driven away from the herd by older and stronger bulls. Frank Bullen, than whom no writer has ever better loved the sea and its creatures, gives the following account of the battle of the bulls in his tale, *The Orphan*:

" But now a time was fast approaching when our hero must needs meet his compeers in battle, if haply he might justify his claim to be a leader in his turn. For such is the custom of the Cachalot. The young bulls each seek to form a harem among the younger cows of the school, and having done so, they break off from the main band and pursue their independent way. This crisis in the career of the Orphan had been imminent for some time, but now, in these untroubled seas, it could no longer be delayed. Already several preliminary skirmishes had taken place with no definite results, and at last, one morning when the sea was like oil for smoothness, and blazing like burnished gold under the fervent glare of the sun, two out of the four young bulls attacked the Orphan at once. All around lay the expectant brides ready to welcome the conqueror, while in solitary state the mighty leader held aloof, doubtless meditating on the coming time when a mightier than he should arise and drive him from his proud position into lifelong exile. Straight for our hero's massive head came his rivals, charging

along the foaming surface like bluff-bowed torpedo rams. But as they converged upon him he also charged to meet them, settling slightly at the same time. Whether by accident or design I know not, but certainly the consequence of this move was that instead of their striking him they met one another over his back, the shock of their impact throwing their great heads out of the sea with a dull boom that might have been heard for a mile. Swiftly and gracefully the Orphan turned head over flukes, rising on his back and clutching the nearest of his opponents by his pendulous underjaw. The fury of that assault was so great that the attacked one's jaw was wrenched sideways until it remained at right angles to his body, leaving him for the rest of his life sorely hampered in even the getting of food, but utterly incapable of ever again giving battle to one of his own species. Then rushing towards the other aggressor the victorious warrior inverted his body in the sea, and brandishing his lethal flukes smote so doughtily upon his foe that the noise of those tremendous blows reverberated for leagues over the calm sea, while around the combatants the troubled waters were lashed into ridges and islets of snowy foam. Very soon the battle was over. Disheartened, sick, and exhausted, the disabled rival essayed to escape, settling stone-like until he lay like some sunken wreck on the boulder-bestrewn sea-bed a hundred fathoms down. Slowly, but full of triumph, the conqueror returned to the waiting school, and selecting six of the submissive cows, led them away without any attempt at hindrance on the part of the other two young bulls who had not joined in the fray."

The manner of whale fishing is practically the same all over the world, and with the exception of the invention of the harpoon gun, little change has ever been made in the methods of capture. A small steamer carries crew,



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OCTOPUS ATTACKING A CRAB

From a photograph by F. Martin Duncan, F.R.M.S., F.Z.S.

Facing page 225.

hauling tackle, and the all-important harpoon gun. When a whale is sighted a small boat containing four or six men puts out from the steamer and approaches the spot as cautiously as possible. The harpoon having been fired, the line flies overboard as the quarry plunges and speeds away, as he hopes, from his pursuers. The boat speeds on too, the tautened line slackens as exhaustion begins to tell on the wounded animal; the oarsmen prepare to backwater as the moment approaches when he must once more come to the surface to breathe. He is sighted; another harpoon is discharged and once more the race begins. At length, however, he is too weak from loss of blood to dive again; the boat creeps up and he is quickly dispatched by lances. Meanwhile, the rest of the herd, with the pathetic stupidity of their kind, circle round and round the stricken one and make no effort to escape. Too often, unfortunately, an entire school may be destroyed, and the steamer sets off in triumph for the whaling station with seven, eight, or nine carcasses in tow. Arrived at the station, the whales are "flensed", the blubber and oil extracted, the flesh dried, and the bones ground up for manure. If the catch has included baleen whales the baleen is carefully taken out and treated in a separate process.

You may possibly have heard about an historic character among the whales known as Pelorus Jack. He is (or perhaps I should write *was*) a Risso Dolphin, to give him his proper name, and he used to haunt the waters of Pelorus Sound between Durville Island and Wellington, New Zealand, where there is a very dangerous strait called French Pass. The queer thing is this: Jack loved to accompany the steamers which were sailing towards the Pass, although he never actually entered it himself. He indulged this passion for years and years, though no one knows why he disported beside the ships. It is one of Nature's riddles.

It is asserted with the utmost emphasis that he did not feed when upon these journeys, and therefore he did not follow the ships for the sake of food which might be thrown overboard.[1] But so persistent were his attentions and so strong the regard in which he was held by the Maoris that many years ago the New Zealand Government thought it advisable to issue a special order in Council protecting "the fish or mammal" as they timidly describe him, known as Pelorus Jack. For fifty years this strange animal was a self-appointed pilot of Pelorus Sound, but he has not been seen since the Great War, and it is feared that he must have fallen victim to a whaler.

There is another great family of sea mammals—the seal folk and their relations. These, the seals, sea-lions, and walruses, are members of the great order of carnivores, and include the animals known as sea-bears, which are the most valuable fur-bearing seals, and sea-tigers. The distinctive point in the habits of these mammals is that they leave the water to breed, and can accommodate themselves fairly comfortably to land travel, whereas the whales have no power of locomotion other than swimming. Baby seals, born on secluded beaches of rock or sand, or on the solid ice, do not take to the water immediately, but, like ducks, need considerable encouragement from their mothers before making the first attempt.

Female seals are very much more numerous than males, so when breeding time occurs each bull chooses a cosy little party of twenty or thirty wives, for whom he fights with the greatest ferocity. The bulls who are unable to obtain any wives, owing to lack of charm or prowess, withdraw to a distant part of the beach, there to spend a morose and solitary season. All too often it is their last season, for the seal hunters have learned the folly of killing females

[1] His natural diet would be cuttle-fish.

and now generally leave the breeding-beaches alone, for which all compassionate hearts must feel thankful. The bachelors, however, are considered fair and lawful prey, and as their beach is well removed from the family quarters they can be slaughtered without any concern on the part of the mothers. The old system of sealing, when mothers and fathers were butchered indiscriminately, was an orgy of appalling cruelty, and was responsible for the loss of entire colonies of seals, since the babies that were too young to kill were left to die miserably of starvation and cold. How far the present-day methods are "humane" is a matter for sad conjecture, but until the rich lose their desire for luxury and the hunter and the trapper the desire for wealth, the cruelties of this and other fur trades will continue, to the undying shame of mankind.

And so, if any reader of this book has learnt from it anything of the wonder and beauty of animal life, let him hereafter spare a thought of pity for the fur animals—trapped and caused to die, without regard for their sufferings, in the way that will hurt the skin least; in order that milady in her carefully-closed car may be wrapped in a coat of lustrous beauty, or milord may have a rug for his well-warmed knees. The woolly sheep may reasonably give his heavy coat to the service of man. In temperate climates there is no need for fur.

However, we are concerned at the moment with the seals' breeding-beaches, where the bulls hold sway over their own families, and the fighting is over, except sporadically. The roaring and baying of the parents, and the whimpering of the pups, make an unimaginable noise. The adults fish continuously for food and in fishing waters—for instance in the mouths of some Scottish rivers where salmon congregate, their depredations are so serious as to make their persecution almost a matter of national

necessity. They are confiding creatures, having a strange affinity for man, and thus it is comparatively easy to kill them. Seals and sea-lions will soon make affectionate and amusing pets, following their human owners about on land by means of their grotesque flippers. It is a difficult matter to keep them sufficiently supplied with fresh fish, and consequently they are not very often adopted by landsmen,[1] though on board ship a seal is not infrequently the sailors' faithful and amusing companion.

The walrus is a cousin of the sea-lion and sea-bear, both of which belong to the class known as eared seals. He is an interesting fellow, valuable on account of his fine ivory tusks and as a source of food and leather supply to Eskimos and other dwellers in the cold regions, and he produces quantities of oil. These useful qualities have led to great slaughter among walruses, which unfortunately must now be reckoned among the forms of life doomed to extinction by man's rapacity. About thirty years ago a dreadful story was told of a party of traders in Northern Canada. At the beginning of winter these men fell in with a party of Eskimos who had made their winter camp near the haunt of a herd of walruses on which they were confidently expecting to subsist until the return of spring. The traders, who must have been men of appalling callousness, deliberately killed the herd, carrying away every part of any value. The Eskimos, thus deprived of their food and oil supply, slowly died of starvation and cold, and the entire tribe is said to have perished.

The sea-elephant, the largest of the seals, and perhaps

[1] According to Dr. E. G. Boulenger, Director of the Zoological Society's Aquarium, a sea-lion can eat between twenty and thirty pounds of fresh fish a day. The walrus and the sea-elephant are even more expensive. A baby specimen of the latter now living in the Zoo consumes thirty pounds of whiting or herrings every day, at a cost of about 4*d*. a pound. When it reaches the adult stature of over 16 feet it is expected that its annual food bill will not fall short of £2000.

of all land animals, is another creature that will soon roam the seas no more. In fact, the Californian species is already extinct. He wears a coating of blubber almost as thick as that of the whale, and a well-grown male specimen may have a girth of sixteen feet and a length of twenty-two feet. He is the hereditary enemy of the seals, and a fight between a herd of sea-elephants and the bulls of a seal colony is a dreadful spectacle. It is melancholy to think that this

Elephant Seal

monarch of the seas, which surely are wide enough to give room to all of Nature's children, should be so ruthlessly destroyed. Presumably, if the real pests of ocean such as sharks, or of tidal waters, such as alligators, had any commercial value, the world would be rid of them for ever within a hundred years. As it is, the useful, beautiful, harmless creatures pay toll. We must not lose our sense of proportion, and it cannot be denied that seals are dangerous rivals to man in the fishing-grounds. But against that we must set the fact that a shark can bite a seal in half and swim away with its prize, and the value of a seal is equal to that of many fish.

CHAPTER XVII

Sea Superstitions

The great oceans and the little seas have been measured and mapped out, sounded and charted, until they are known almost to their uttermost bounds. The roving sons of men in all ages have explored with such perseverance that there is little left to the imagination now, and it is no longer necessary to speak of the " known world ", for all, or nearly all, is known. But let the mind roam back to the time when nothing was known, and the primitive imaginations of men but recently raised to manhood had full play.

The ocean, vast, and unexplored, was the home of things infinitely evil and terrible. The dwellers on its shores knew something of the slimy monsters which occasionally might be seen coming to the surface. What of those they could not see? They knew something of the ruthlessness and brutality of their fellow-men. What might there not be of ferocity in distant lands they had never visited?

The first mariners ventured on the sea in spite of the most deadly fears and perils that can ever have beset men. When they came back they were able to deny some legends, but they had acquired fresh ones to take their places. Iago, the Great Boaster, " He the marvellous story-teller ", was always among them, no doubt, ready to provide imaginative embroideries even to voyages which were uneventful. We may take it, too, that genuine hallucination also played its part, for men drunk or starving, or merely mazed in

ignorance, may see all sorts of non-existent things. So, by the time the Middle Ages were reached, the way of the sea was wrapt in such a mist of fable and false belief that the amazing thing is that anyone would venture out of sight of land at all. Yet it is the period of the most daring of all voyages.

Only towards the west, where sunset glow lent enchantment and glamour to imagined wealth, and it was believed that Elysium beckoned, did any day-dreams of beauty and happiness tend. To southwards, it was well-known—until the expeditions sent out by Prince Henry of Portugal in the fifteenth century disproved it—that any sailors bold enough to pass Cape Bojados on the coast of Africa, just south of the Canaries, would turn black, and that still farther south the rays of the sun came down as liquid flame. Northwards, in the land called Iceland, many fearsome things existed, having their origin, doubtless, in the volcanoes and geysers, which men believed, according to Richard Hakluyt, to be "hel-mouth and purgatorie". And to quote the same authority, "Not far from these Islands (namely the Hebrides, Iseland, &c.) towards the north there is a certain wonderful whirlpoole of the sea, where into all the waves of the sea from farre have their course and recourse, as it were without stoppe; which, there conveying themselves into the secret receptacles of nature, are swallowed up, as it were, into a bottomless pit, and if it chance that any shippe doe passe this way, it is pulled, and drawen with such a violence of the waves, that eftsoons without remedy, the force of the whirlpoole devoureth the same."

No doubt this was the Maelström, a vortex of sufficient fury to strike terror into the stoutest heart, and sinister enough to give rise to any number of wild stories of similar and more dreadful occurrences in other seas. Another

thing which perplexed mariners was the variation of the compass—Columbus's men were moved to mutiny thereby—and this phenomenon no doubt gave rise to the legend of the Lodestone, which was believed to be an enormous mass of magnetic rock of so powerful attraction that vessels were drawn to it willy-nilly and held fast without possibility of escape.

The forces of Nature, however, cruel and irresistible though they might be, were less to be dreaded than the forces of the supernatural, through which a man might lose his soul. One of the oldest of all the western ocean superstitions is that of the siren, the beautiful maiden seated on a rock, combing her long golden hair, and singing in a voice of entrancing sweetness. Poor sailor-men, doomed to pass many months in the squalor and confinement of a ship, with only the roughest companions, would find it hard to withstand such allurements. Yet if they yielded and approached the siren, she drew them down under water to their eternal damnation.

In Greek mythology there were three of these sirens or sea-nymphs. If you have read the *Odyssey* you may remember that Circe bade Ulysses stop the ears of his companions with wax, and lash himself to a mast, lest they fell victims to the fatal songs. Yet in spite of those precautions the Argonauts only got safely past the sirens through the good offices of Orpheus, who protected them by singing songs still more beautiful. Then the sirens flung themselves into the sea and were transformed into rocks, for the legend, if you remember, required that if any seaman could resist the magic music, the sirens themselves must die.

Such were the sirens of classic mythology; and it is very easy to trace a strong family resemblance between this myth and the much more persistent legend of the mermaid. In fact, the mermaid was only a siren under another name;

and if one asks, did anyone ever seriously believe in mermaids, the answer is that those delightful sea-damsels were actively engaged in the superstition business within a hundred and fifty years ago. As late as 1822 a mermaid was exhibited in a glass case in Piccadilly, at a charge to the public of half a crown a head, and although the exhibit was shown to be a fraud compounded of the head and body of a dried monkey joined to the tail of a fish, that disclosure does not appear to have had much ill-effect on the financial success of the exhibition. There are circumstantial records of a merman (or a merboy, rather, since observers put his age at 16) in Milford Haven in 1782, and of a mermaid off the coast of Caithness who secured a good deal of newspaper publicity in 1809. One can find recorded mermaids, up and down the coasts of Europe, by dozens.

When we come to examine the foundations of the mermaid myth we find very small basis for its persistence. It is generally supposed to have originated in the peculiar habits of a very remarkable race of animals known as sea-cows. These strange mammals have no relationship with the cetaceæ, but belong to a natural order called *Sirenia*—a name which at once suggests (as it was intended to suggest) a connexion with the sirens. There are now but two races of *Sirenia*, the dugongs and the manatees, and they are strange, less because they may have given rise to the mermaid superstition, than in a zoological sense—they don't link up properly with other animals. All that matters for us now is that the sea-cows are large, sluggish animals—they may be ten feet long—gentle and inoffensive, that are rapidly dying out. The dugongs are found now only in the Red Sea and on the coast of East Africa, in the Indian and Pacific Oceans, and the waters of Northern Australia; while the related manatee is confined to the

tropical belt on both sides of the Atlantic. But they were once more numerous and probably more widely distributed.

The poor dugong, which has a dark, fish-shaped body, seems to have a habit of sitting erect on its tail with the upper part of its body out of water, or it can scramble on to a rock by the aid of its flippers and sit in the same position there. Golden hair it has none, nor golden comb, and although it may bark and whine, considerable distance must be necessary to lend enchantment to the sound. The female nurses her baby in this erect position, and as the breasts are on the level of the arms, she thus assumes a slight human resemblance, and on this the whole mass of mermaid superstition appears to rest. This most harmless of creatures has for centuries been credited with diabolical treacheries, when all it asks of life is a nice rich field of seaweed on which to feed and a nice sunny rock to sit on. What did it want with sailor-men?

Now, how do we account for the numberless stories of captured mermaids, such as were common in European countries up to within a hundred and fifty years ago? Read, for instance, the description published in the *Annual Reviewer* of 1775, of a mermaid which had been caught in the Grecian Archipelago, and brought to London for exhibition: "It has the features and complexion of a European. Its face is like that of a young female; its eyes of a fine light blue; its nose small and handsome; its mouth small, its lips thin, and the edges of them round like those of a cod-fish; its teeth small, regular and white; its chin well-shaped, its neck full; its ears like those of the eel, but placed like those of the human species, and behind them are the gills for respiration which appear like curls. Some mermaids are said to have hair upon the head; but this has none, only rolls instead of hair, that at a distance may be mistaken for curls. But its chief ornament is a

beautiful membrane or fin, rising from the temples, and gradually diminishing till it ends pyramidically, forming a foretop like that of a lady's head-dress. It has no fin on the back, but a bone like that of the human species . . . its arms and hands are well proportioned but without nails on the fingers. . . . From the waist downwards, the body is in all respects like a cod-fish. It has two sets of fins, one above, another below, the waist, which enable it to swim out to sea; and it is said to have an enchanting voice, which it never exerts except before a storm."

Here is a wealth of detail, yet one wonders whether the writer ever saw the exhibit, since it was afterwards declared to be a fraud made out of a shark's skin! As far as can be judged, all similar tales are either deliberate frauds or unconscious elaboration. It may safely be said that no really credible eye-witness of a mermaid's toilet has left a written account of what he saw. He has told somebody who told somebody else, and so on, until at fourth- or fifth-hand the story has reached someone who thought it of sufficient interest to write down.

The same absence of authority is true of the legend of the Flying Dutchman. No reliable witness ever encountered that terrible spectre of the South Atlantic, or, at least, left any record of his encounter. But if you think that sailors never took him seriously, you make a sad underestimate of the sailor's powers of credulity in the days before steam. He was a very potent force in the hazards of the seas for several hundred years, and in some ways the story of the Flying Dutchman is more easily credible than most sea legends—mermaids for instance.

Everyone knows how the forlorn Vanderdecken—the Dutch call him Van Straaten, and the Germans Herr von Falkenberg, and he is also identified as one Bernard Fokke —drifts in his spectral ship for ever without a steersman,

playing at dice with Satan with his own soul for stake. Van Straaten, Vanderdecken and Bernard Fokke are to be met with off the Cape of Good Hope, but Herr von Falkenberg is a myth of the German Ocean. Different reasons are given for his dreadful curse, for there are many variants of his story, but blasphemy is the cause usually assigned. In some versions the punishment is attributed to his persistence in trying to round the Cape in the teeth of a terrific storm in spite of the entreaties of his passengers and crew, and even of an angel sent to warn him.

Whatever his crime, an encounter with the Flying Dutchman was always terribly unlucky. He had the power to disguise himself and his ship, so that he should not be recognized, and clearly he had a crew, of some sort, for he was known to hail passing ships; even to ask for stores, or to beg that letters might be carried home. Well, that was the beginning of the end, for the vessel spoken. Ill-luck, famine, pestilence, or storm dogged her voyages ever after, and such of her crew as ever reached port were doomed to an evil fate.

Good material for a hundred stories of the supernatural, it is not to be wondered at that Vanderdecken raised the hair of poor ignorant sailor-men. For, mark you, there may have been a veritable Dutchman of the seventeenth century who carried his ship to disaster, through folly or madness, somewhere off the Cape, even though we have no authentic record of him. It seems odd, perhaps, that this particular sea-myth can be so accurately dated. Mermaids are 3000 years old, at least—why should the spectral Dutchman have only a paltry 300 years behind him? It is here that we touch the most interesting thing in his story. For we find that the Flying Dutchman connects up with Flying Greeks and Flying Russians—even Flying

South Sea Islanders and Flying Chinamen—just in the way that the great folk-tales and fairy-tales join the scattered races of mankind into a group of children telling stories around a single hearth. So the Flying Dutchman becomes one of the world's great ghost stories—a tale of a phantom ship that you may yet encounter in any of the Seven Seas.

Let us leave myths for realities. Though you may never meet a mermaid nor catch a glimpse of a spectral ship, if you go to sea you are fairly certain, sooner or later, to come under the influence of St. Elmo's Fire, which to a sailor used to be a very terrifying experience. To this most beautiful manifestation of atmospheric electricity superstitious fears have always been fixed, except among the Greeks, who wisely regarded its appearance as a good omen. Truly it is eerie and mysterious, yet so lovely a thing that one marvels that its coming could be anything but a delight. On a dark night it comes, and usually a quiet one, and then about masts and yards appears a faint, white, ghostly glow; or points of light move like will-of-the-wisp hither and thither among the rigging. You may perceive that a seaman aloft wears a halo, or the light may pour from your fingers as you touch a rope. There may come a roaring of wind and a deluge of rain, but the strange, soft, unearthly light heeds them not, but moves from point to point, never quite stationary, never quite permanent anywhere. That is St. Elmo's Fire, known also on our east coasts as composants, corposants, and other corruptions of its Italian name of *corpus santo* or holy body. It arises, as you may suppose, from a highly electrical state of the atmosphere. And that's as near as we can get to cause and effect without going rather deeply into static electricity. But it's as harmless as air and the saint whose name it bears—though who he was I can't say, for he has no place in the calendar, and his identity is wrapped in mystery.

Yet Spanish sailors have adopted Elmo as their patron saint, claiming him to have been the Syrian martyr St. Erasmus. Other names for the same thing are fire of St. Elias, St. Clara, or St. Nicholas.

Directly traceable to an historic event, the belief in "Jonahs" must be one of the most widely-spread of all superstitions. How old it is there can be no imagining, for his shipmates were inquiring for a Jonah when they decided on the authentic Jonah who has given his name to all unfortunate bringers of ill-luck ever since. The poor man on whom the stigma of Jonah rests has a miserable time amongst his fellows, who can by no means be convinced of his innocence. Let but a few minor accidents occur at the beginning of a voyage, the word goes round, "We've a Jonah aboard", and all hands join in the work of detection. Of course no sailors nowadays would go the length of putting the worst of Jonahs overboard, but no doubt they would not shrink from making his life so unbearable that he would be ready to desert as soon as the ship touched land.

Somewhat similar, though not so sinister in its conception or results, is the superstition that has gathered round Finnish seamen. These, of all sailors the most peaceable, hard-working, and efficient, are known by their mates as holders of magic power. This power may be manifested in a hundred different ways, so many and varied are the legends that have grown up around the stolid square-faced Finn. He is believed to be able to provide his friends with favourable winds, while those who have incurred his displeasure could only expect bad weather. The Finn on board has, in fact, an extremely comfortable time. Let him but turn his cap round as he holds a jug to the water-breaker, and whatever drink he fancies will run from the tap. Is he tired of salt pork and biscuit? Then let him

plunge his knife into the foremast and any food he likes to demand will be substituted for the ship's diet. The rats on the ship are the Finn's obedient servants, and have his goods and chattels in their especial charge, to the end that nothing of his may ever be lost; while the birds are his devoted messengers, and by carrying his news ashore save him the trouble of writing letters.

But the sailor's whole life is, or used to be, governed by a mass of superstition. In the old sailing days no seaman would go to sea on a Friday, and he who was so bold as to whistle on board would be set upon for calling up a storm. Whistling, you must understand, was a direct invocation to the devil—as "the prince of the powers of the air". Because witches had obtained a share of the control of those powers, they were always potent forces with sailors, who took care to keep on the right side of them by paying tribute in cash. According to *The Gentleman's Magazine*, the old hags of Norway used to sell winds to seamen, even so late as 1822, the date of my volume of that interesting guide to peculiar information. From witches, too, the Lapps and Finns used to buy wind, and took it to sea with them, according to the same authority, neatly tied up in bags, ready for use when the need arose.

Another heinous crime at sea is to burn or destroy or make any use of paper bearing Scriptural passages printed upon it; while from some contrary impulse comes the dislike of having a clergyman on board, as he carries ill-luck. A death at sea is regarded as an infallible precursor of a storm, while the belief that sharks follow a ship on which there is illness is doubtless based on the fact that sharks always follow a ship, anyhow. To sing certain songs or chanties is to court disaster. Rudyard Kipling, in *Captains Courageous*, gives a vivid picture of the hair-raising experience of Dan and Harvey, after Dan had been so daring

as to buy the knife of a dead Frenchman—a knife reputed to have killed a man. Dan gives the knife to Harvey, when the two boys are alone in the dory, fishing in a dense fog. Such as have read Kipling's capital yarn will remember how the Frenchman comes back for his knife—on Harvey's line.

"They pulled together, making fast at each turn on the cleats, and the hidden weight rose sluggishly.

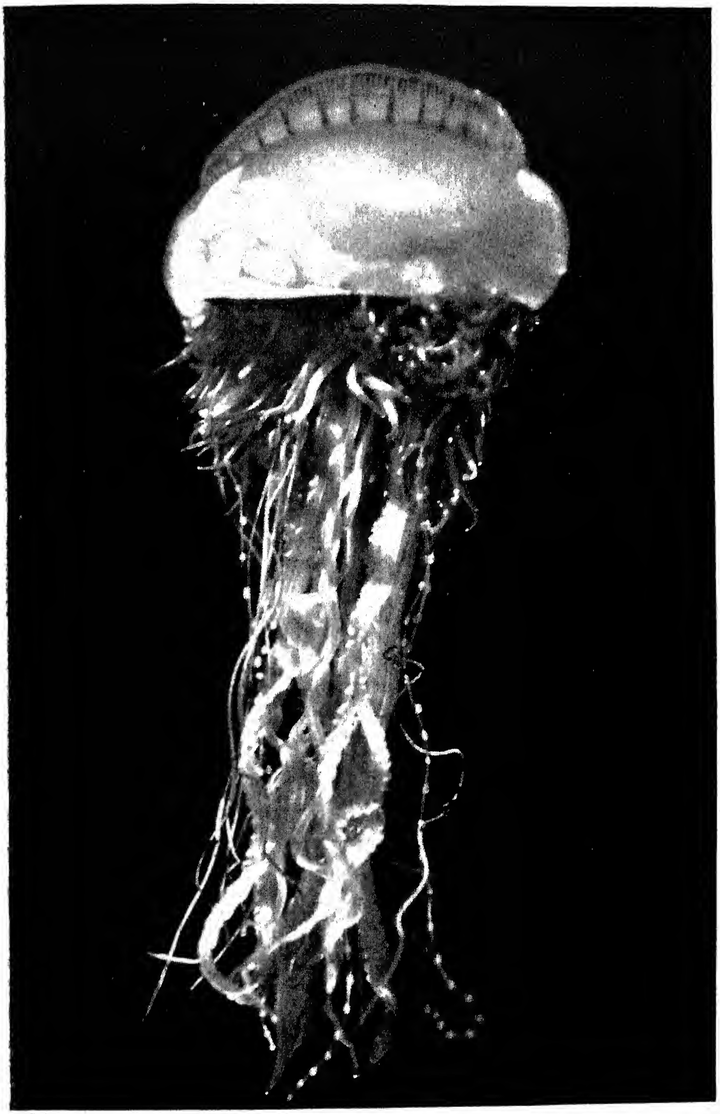
"'Prize, oh! Haul' shouted Dan, but the shout ended in a shrill, double shriek of horror, for out of the sea came —the body of the dead Frenchman buried two days before! The hook had caught him under the right arm-pit, and he swayed erect and horrible, head and shoulders above water. His arms were tied to his side, and—he had no face. The boys fell over each other in a heap at the bottom of the dory, and there they lay while the thing bobbed alongside, held on the shortened line."

The terrified boys are convinced that the curse of the Frenchman rests on the possessor of his knife, and Harvey struggles desperately to undo the buckle of the belt to which it is attached. At last it is flung far overboard, and the fishing line is relieved of its dreadful burden, and then, as they grow calmer, Harvey suggests that "it couldn't have been meant" and that the corpse was brought up to their boat on the tide. But by that suggestion Dan is not appeased:

"'Tide! He come for it, Harve. Why, they sunk him six mile to south'ard o' the fleet, an' we're two miles from where she's lyin' now. They told me he was weighted with a fathom and a half o' chain cable.'

"'Wonder what he did with the knife—up on the French coast?'

"'Something bad. Guess he's bound to take it with him to the Judgment. I'd give a month's pay if this fog 'ud lift. Things go about in a fog that ye don't see in clear



E 328

A "MAN-OF-WAR"

A jelly-fish whose scientific name is *Caravella Caravella*. A beautiful colony consisting of a float from which are suspended numerous individuals, some nutritive, some locomotor, some tactile, and some reproductive.

From a photograph by W. S. Berridge, F.Z.S.

weather—yo-hoes an' hollerers an' such like. I'm sorter relieved he come the way he did instid o' walking. He might ha' walked.' "

To lay the ghost of the poor Frenchman, that night "the cook put a lighted candle, a cake of flour and water, and a pinch of salt on a shingle, and floated them out astern."

But tales like this belong, with so much that appeals to the imagination, to the days that are gone; the days of the sailing vessel. Elementary schools, machine-shops, and steamers together have produced a new race of seamen, to whom belief in anything, whether natural or supernatural, is a difficult attainment. For them ships may leave port on any day of the week, Fridays included, whistling is appreciated, and St. Elmo's Fire noted as a curious phenomenon. Yet in spite of "modern improvements", the *envoie* offered to Richard Chancelor in 1553, on his starting for a voyage of discovery to the north-east, quoted by Hakluyt, might well be made to any and every sailor to-day:

"You are also to remember, into howe many perils for your sakes, and his countrey's love, he is nowe to runne; whereof it is requisite that we be not unmindfull, if it please God to send him good successe. We commit a little money to the chaunce and hazard of Fortune; He commits his life (a thing to a man of all things most deare) to the raging Sea, and the uncertainties of many dangers.... We shall keepe our owne coastes and countrey; He shall seeke strange and unknowne kingdomes. He shall commit his safetie to barbarous and cruell people, and shall hazard his life amongst the monstrous and terrible beastes of the Sea."

CHAPTER XVIII

The Port of Missing Ships

"And the women are weeping and wringing their hands
For those who will never come home to the town."

Shipwreck, alas! is almost as old as the moaning of the bar. Ship after ship has left harbour, never to return or send tidings of its whereabouts. Throughout what we may call the exploring age—that is up to the end of the seventeenth century, or perhaps a little later—many were the ventures which reached the port of missing ships. This, of course, cannot be regarded as surprising, for the entire absence of communications in all but a few patches of the earth's surface, quickly put sea-rovers out of touch with their fellows. The great distances absorbed them and their passing was silence. But for the last hundred years, ever since the coming of steam, in fact, the oceans have become more and more recognized waterways. Definite "steamer-lanes" cross and recross from one continent to another, and shipping tends to congregate very much in the same areas. Ships, too, have been growing ever larger, and carrying greater numbers of people, so that in the case of a disaster there is a greater chance of some survivors living to tell the tale. Even so, a study of *Lloyd's list* reveals an astonishing number of vessels posted as "missing"; and although the fate of those ships is ultimately traced, closer investigation will lead us to some curious stories.

The epic of sea mysteries is embodied in the finding of

the *Mary Celeste.*[1] The word "finding" is used advisedly, for if the *Mary Celeste* had been lost there would, in those pre-wireless days to which she belonged, have been nothing strange enough to call for comment. Wreck, disaster—even total loss are among the ordinary risks of ship-owners. But the *Mary Celeste* was not lost. She was found.

Towards the close of the year 1872, two old cronies, Captain Morehouse of the brig *Dei Gratia* of Nova Scotia, and Captain Briggs of the brig *Mary Celeste*, met to dine together on the night before the *Mary Celeste* was due to sail for Genoa. Briggs, a man of about forty-five, was a seaman of great experience. He took his wife and child with him on the ship, in which he held shares. On the day following his meeting with Morehouse, 7th November, 1872, to be exact, Briggs started on his voyage, and a few days later the *Dei Gratia* also set out, for Gibraltar.

Now when the *Dei Gratia* had reached a point about three hundred and eighty miles from the Portuguese coast, she sighted ahead of her a brig, and on closer approach, a rather strange circumstance appeared. The brig, which had all sails set, was on the port tack, whereas her headsails were set to starboard. Great was the surprise of Captain Morehouse to recognize the brig as the *Mary Celeste*, and he immediately signalled to her. His signals were unanswered; the *Mary Celeste* held on, but not as if well steered, and in fact, there was no sign of life on board. The mate of the *Dei Gratia*, on being asked what he thought of it, supposed that the crew were all below drunk.

Knowing his old friend to be a strict teetotaller and something of a disciplinarian, Captain Morehouse decided the matter needed looking into, and sent the first mate and

[1] The name of the vessel has been often wrongly given as *Marie Celeste*, or *Marie Céleste*. There seems to be no doubt, from entries in the American Maritime Register, *Lloyd's List*, and the official documents relating to her salvage, that the name was actually *Mary Celeste*.

a couple of men in a boat to investigate. Still meeting with no response to their hails, the first mate and one of the men clambered on board, and soon after signalled to Captain Morehouse to join them. For here was something no sailor-man could understand. A sound, orderly ship, well provisioned, perfectly seaworthy, yet abandoned by her captain and crew in mid-ocean. Together Captain Morehouse and the mate made a careful examination of the whole vessel. The log was in order, made up to the end of 24th November, and entries on a slate lying on the table continued the record of the brig's progress up to 8 a.m. on 25th November, exactly ten days before.

The details noted in the cabin make pathetic reading, in view of the subsequent possibilities. On the table was a sewing-machine with a little garment in course of stitching. The captain's wife, doubtless, was the seamstress, and her thimble and reel of cotton, and an oil-can for the sewing-machine, lay beside her work. The harmonium was open and a sheet of music stood upon the rack. The mate had just begun to write a letter to "Fanny, my dear wife—" in fact, all the persons on board had apparently been at their usual occupations when that unfathomable *something* occurred which caused them all suddenly to withdraw from the ship. That there was no time allowed for preparation seemed to be proved conclusively by the finding of a five-pound note and many articles of value; the captain's chronometer alone was conspicuous in absence. Such being the circumstances Captain Morehouse did the only possible thing and put his mate and two men on board to work the derelict to Gibraltar.

At Gibraltar, a searching examination into all aspects of the case was made, and report sent to the British Board of Trade by Mr. Solly Flood, "Her Majesty's Advocate-General and Proctor for the Queen in her office of Admiralty

and Attorney-General for Gibraltar". As his report may be taken as unquestionable it may well be quoted in part. After stating the facts of the finding of the *Mary Celeste*, and her salvage, he proceeds:

". . . the wind being from the north, and the *Dei Gratia*, consequently on the port tack, they met the derelict with her jib and foremast staysail set on the starboard tack. . . . But the account which they gave of the soundness and good condition of the derelict was so extraordinary that I found it necessary to apply for a survey, which was held in my presence on the 23rd of the same month, and the result of which is embodied in the affidavit of Mr. Ricardo Portunato, a diver, sworn on the 7th inst.; of Mr. John Austin, Master Surveyor of Shipping, sworn on the 8th inst., and Mr. T. J. Vecchio, sworn on the 9th inst. From that survey it appears that both bows of the derelict had been recently cut by a sharp instrument, but that she was thoroughly sound, staunch, and strong, and in every way seaworthy and well-found; that she was well-provisioned, and that she had encountered no seriously heavy weather, and that no appearance of fire or of explosion, or of alarm of fire or explosion, or any other assignable cause for abandonment, was discoverable. A sword, however, was found, which appeared to me to exhibit traces of blood, and to have been wiped before being returned to its scabbard. Opinion in this respect having been corroborated by others, I proceeded on the 7th inst. to make, with the assistance of the Marshal of the Vice-Admiralty Court, a still more minute examination for marks of violence. . . . On examining the starboard top-gallant rail, marks were discovered, apparently of blood[1] and a mark of a blow, apparently of a sharp axe. On descending through the fore hatch, a barrel,

[1] These marks, and also those on the sword, were analysed and found to be only rust.

ostensibly of alcohol, appeared to have been tampered with. The vessel's Register, Manifest, and Bills of Lading have not been found, neither has any sextant or chronometer been found. On the other hand, almost the whole personal effects of the Master, and, as I believe, of his wife and child, and of the crew, have been found in good condition. They are of considerable value. . . . My own theory or guess is, that the crew got at the alcohol, and in the fury of drunkenness murdered the Master, whose name was Briggs, his wife and child, and the chief mate; that they then damaged the bows of the vessel, with the view of giving it the appearance of having struck on the rocks, or suffered collision, so as to induce the Master of any vessel which might pick them up, if they saw her at some distance, to think her not worth attempting to save."

Such, then, are the known facts relating to the *Mary Celeste*. Needless to say, the story led to endless surmise. Various writers, beginning with the late Sir Arthur Conan Doyle, made it the theme of fiction told as fact, purporting to have been revealed by actual survivors of the dis ter. But all these so-called solutions show errors in such demonstrable matters as the size of the ship, her position on certain dates, the names and numbers of the crew, and the personalities of the captain's wife and child, while some of them have not shrunk from smirching the character of Captain Briggs, who on the testimony of all who knew him was a sober, God-fearing man. Besides, all the explanations were based on a fundamental mistake. The authors went to immense pains to weave stories which provided a means of escape for the crew without the use of the ship's boats. The boats, they say, hung in the davits when Captain Morehouse made his discovery. But that was not the case. The boats were missing, and the truth is that the *Mary Celeste* sailed from New York with only one boat, a yawl.

To Mr. J. G. Lockhart, who spent years in collecting the facts of this strange event, the world is indebted for the sanest explanation. In his book *A Great Sea Mystery*, Mr. Lockhart assigns the cause to the cargo of crude alcohol carried by the *Mary Celeste*. In a high temperature, such a cargo might generate gases inflammable enough to cause small explosions, which might even lead to an explosion of the whole cargo. Suppose an escape of gas were noticed, or rumblings were heard in the casks, or even a small explosion took place. When one of the hatches was removed for investigation possibly more alarming symptoms were noticed, and in fear of imminent explosion the entire party took to the yawl. No one lingers on a ship that he thinks is about to blow up. Then what happened is not so mystifying. Either they tried to keep up with the brig and failed, or they tried to make the island of Santa Maria, 370 miles away, and failed. The likeliest thing is that a sudden breeze took their ship away from them. When Captain Morehouse boarded the *Mary Celeste* the wind blowing through the open hatch had dissipated any sign of gas.

Another unexplained tragedy of the sea was the passing of the *Waratah*. This fine steamer of the Blue Anchor Line, of 16,800 tons, was launched in 1908, listed by Lloyd's 100 A1, and put into service between London and Australia. On her second voyage she arrived at Durban on 25th July, 1909, on her homeward journey, and after coaling, set out again, with ninety-two passengers on board, for Cape Town. On the morning of the 27th, she was hailed by the *Clan MacIntyre*, a slower ship proceeding in the same direction, and the two ships exchanged greetings. She remained in view of the *Clan MacIntyre* for some hours but finally disappeared below the horizon. The *Clan MacIntyre* encountered bad weather, in fact on the next day it blew a hurricane.

As it afterwards transpired, the *Clan MacIntyre* had received the last known communication from the *Waratah*, which was never seen or heard of again. Yet the place of her disappearance was a stretch of ocean close in-shore, and, from a seaman's point of view, thronged with traffic. The *Clan MacIntyre*, in the forty-eight hours following her sight of the *Waratah* sighted ten other ships, but none of these ever reported seeing the *Waratah*. Still more strange is the fact that no wreckage was ever found. When it became clear that some disaster must have overtaken the *Waratah*, three warships, a ship sent by the Australian Government, and the *Sabina*, a search-ship dispatched by the Blue Anchor Line (which hunted for nearly three months and covered over 14,000 miles) thoroughly combed the Southern Ocean for trace of the missing ship, but without result. This big ship, of approximately 17,000 tons, carrying a cargo of 10,000 tons, a ship's company of more than a hundred, and passengers to the number of ninety-two, had simply disappeared, leaving no trace.

It must be admitted that one or two boats passing along the same route brought tales of having seen bodies in the water, but these tales were never substantiated. One in particular referred to the body of a little girl in a red dressing-gown, which was seen by several persons. The captain of one ship, the *Tottenham*, being told of the circumstances, put back and returned to the place where the bodies were reported to have been seen, but satisfied himself that a mistake had been made, and it was afterwards very definitely asserted by the chief engineer of this ship that "the little girl in the red dressing-gown" w a large packet, apparently of printing paper, with a red wrapper round the middle. There is no gainsaying the fact that none of the many vessels making the same journey, and none of the five search ships, ever found a fragment which

could be identified as coming from the *Waratah*, or ever saw the body of one of her passengers or crew. She disappeared, as though the sea had opened and swallowed her up.

The necessary sequel to the tragedy was the Board of Trade inquiry held in London. As was only to be expected, the wildest rumours were being circulated relative to the condition of the *Waratah* at the time of her sailing; such as, that her cargo was badly stowed, that she was unhandy and unseaworthy, that she had a bad list, that she rolled badly, and so on. The evidence contradicting these theories was of course of a technical nature, and many experts were called upon to give their opinions. Here was a new ship, little more than a year old in commission; the builders and designers were eager and able to defend their work, the owners anxious above all things to defend their integrity, and the inspectors of the Board of Trade, Lloyd's, and the Emigration Authorities virtually on trial for their part in passing as sound a ship that had been lost. Against them was ranged public opinion, that great voice which utters its judgments on any and every subject without very deep or careful consideration. Obviously Rumour and Public Opinion could not be called as witnesses, but several persons who had sailed in the *Waratah* came forward to relate their experiences. Their general purport was that they thought the *Waratah* had a heavy list and a bad roll from which she was slow to recover. They were doubtless sincere, and they may have been accurate, but they had had eighteen months between the date of the disaster and the holding of the inquiry in which to refresh their memories of their sensations on board, and to rehearse their evidence in frequent conversations with their friends. The finding of the Court implied that it was satisfied that there was no structural defect in the ship, that she had sufficient stability,

and was in a seaworthy condition, so far as the evidence went. For the rest, it may be said that nothing has happened in the twenty-one years since the *Waratah's* loss to cast the least new light on the mystery of her disappearance.

Quite recently, in fact so recently that an explanation may yet be forthcoming, another strange story has been added to the long, long roll of sea mysteries.

The Danish training-ship *Köbenhavn* left Montevideo on 14th December, 1928, for Australia, where she was to load wheat. She had on board forty-five Danish cadets, and officers and crew to the number of fifteen. A week later she was seen by a Norwegian steamer and was then about nine hundred miles west of Tristan da Cunha, and that is the last that is definitely known about her.

The *Köbenhavn* was a five-masted barque—a distinctive type of vessel of which, according to experts, there have only been six examples in the whole history of sail. She was painted black, with a broad white band, and was a fine, well-found ship, equipped with wireless and an auxiliary engine. Yet no message of distress was ever received from her, and no single survivor or piece of wreckage has appeared in spite of prolonged and systematic search by special ships. Her voyage in the ordinary course would take her through the high southern latitudes where fog and storm are the natural weather, and peril from ice is never very far distant. The theory generally accepted at the time of her disappearance was that she must have been destroyed by collision with the ice.

But hear the sequel. Mr. Phillip Lindsay, a lay preacher on Tristan da Cunha, on being relieved after three years' service returned to civilization with a curious tale to tell of a "phantom barque". This is his story, recorded in *The Times* of 9th April, 1930:

"Long before I knew that the ship was missing, I could

describe her fairly accurately. She was five-masted, but her fore or mainmast was broken. A huge white band round her hull was the most prominent mark. It was on 21st January last year that she passed. . . . When still a long way off (possibly 7½ miles) she seemed to be drifting to the eastward, and it was at this time that we watched her most. The sea was rough for our boats, which are only made of canvas, and so we could do nothing but watch her gradually crawl past and run inside the reefs to the west side of the island.

"She was certainly in distress. She was using only one small jib, which appeared to be set from the bow to the broken mast, and her stern was very low in the water. It was almost down to the white band round her hull. This was all seen through glasses from a distance of about three and a half miles, so that we could hardly be mistaken.

"The usual charts of Tristan have no reefs marked on them, and this is very dangerous, as the island is pretty well reef-bound. I estimated that she was within a quarter of a mile of the shore when we last saw her, and the reefs stand out about a mile and a quarter, so she must have been well inside. We saw her no more after that, and the place where she went in was quite inaccessible."

Think of it—a coast so rocky and bound by reefs that no boat can get near enough to see into the bays and inlets from the sea, and a landward surface so sheer that no one can climb to the top of the cliffs to look down into them. Only an aeroplane could survey these desolate corners of earth—and aeroplanes do not fly in Tristan!

Mr. Lindsay concludes:

"Several things were afterwards washed up, but I cannot say that they were from the *Köbenhavn*. . . . It would have been impossible for the ship to drift free of the reefs again, once being bound by them."

Clearly, Mr. Lindsay's story rules out the theory that the *Köbenhavn* foundered after collision with an iceberg, though as to that, there were not wanting experts who pooh-poohed the ice theory from the first. Yet there are others who hold that it is by no means certain that the ship observed at Tristan can be identified as the missing *Köbenhavn*, in spite of her very distinctive character, and the broad white band around her hull. At 3½ miles, the nearest distance at which she was seen, it is not at all easy to pick out the details of a ship. In any case five-masted barques are rare; and in any case it is safe to assume that the barque that drifted inside Tristan reefs was derelict. In what tragic chain of events that fine ship sought thus her grave among those reefs we shall probably never know. Perhaps, as we concluded in the case of the *Mary Celeste*, a sudden alarm caused the company to take to the boats, meaning to keep the vessel in sight and to return to her if she survived some threatened disaster, only to lose sight of her in the almost perpetual fogs of the region. Whatever explanation we seek, it seems to lack probability, and the passing away of the *Köbenhavn* is a complete mystery.

Once again let us find a fitting thought in old Hakluyt, our great sixteenth century sea-scribe.

"But if it be so, that any miserable mishap have overtaken them: if the rage and furie of the Sea have devoured those good men, or if as yet they live, and wander up and downe in strange countreys, I must needs say they were men worthy of better fortune, and if they be living, let us wish them safetie and a good returne; but if the crueltie of death hath taken holde of them, God send them a Christian grave and Sepulchre."

What better farewell?

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(Illustrations shown by *italics*)

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